Comments on the CA Water Plan Update 2013

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Sent: Tuesday, December 03, 2013 12:49 AM

To: DWR CWP Comments

Attachments: California Water Plan Upd~1.docx (27 KB) ; Vol3_Ch04_FloodMgt_PublicR~1.pdf (250 KB) ; Vol3_Ch09_ConjMgmt-GW-Stor~1.pdf (1 MB) ; Vol3_Ch16_GWAquiferRemedia~1.pdf (146 KB) ; Vol3_Ch26_Sediment_PubRevi~1.pdf (338 KB)

Please accept the attached comments from the Orange County Water District. The first attachment contains a word file with all submitted comments. These comments are also added to each section with sticky notes in the following four attachments. Thank you.

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COMMENTS OF THE ORANGE COUNTY WATER DISTRICT on the

California Water Plan Update 2013 – Public Review Draft, Volume 3 Resource Management Strategies

Submitted on: December 2, 2013

Please accept the following comments and proposed language changes to the Public Review Draft as suggested below. Proposed new language changes are indicted by underlined text and suggested deletions are indicated by text with strikeouts.

Volume 3 Chapter 4 Flood Management

Page 4-7 Line 16: Restoration of flow of sediment that accumulates behind flood control dams has multiple benefits including increasing water storage capacity for flood control and water conservation, improving downstream riverbed habitat, reducing streambed incision, and providing sediment for beach replenishment.

Suggested text changes:

Page 4-7 add text on line 16 as follows: levees, restoring channel alignment, removing unnatural hard point within channels, restoring flow of sediment that is trapped behind dams, or…

Volume 3 Chapter 9 Conjunctive Management & Groundwater

Page 9-9 Line 2: Reference is made to a report 'California's Groundwater – Update 2013' but this report is not available for review and comment. We request that this report be provided in draft form for public comment prior to the report being finalized and prior to the information in the report being used in the CA Water Plan Update 2013.

Page 9-10 Line 26: The report states that there is no comprehensive statewide data-monitoring network for planning and implementing conjunctive use. There is an extensive amount of planning and implementation of conjunctive use of surface water and groundwater occurring through the Integrated Regional Watershed Management programs and other efforts. It is not clear why a new statewide database is needed. Prior to developing a new statewide database, a need and purpose for such a database should be provided. There is already extensive coordination of conjunctive use underway.

Suggested text changes:

Page 9-10 Line 26: ~~Although t~~ The groundwater elevation monitoring provisions of the CASGEM Program has increased availability of information useful ~~are~~

> ~~steps in the right direction, there is no comprehensive statewide data-monitoring network~~ for planning and implementing conjunctive management <u>in the state</u>.

Page 9-23 Lines 15-17: This section states 'Expedite environmental permitting for implementation of conjunctive management, recharge, and water banking facilities when facility operations increase ecosystem services, and includes predefined benefits/mitigation for wildlife and wildlife habitat.' OCWD recommends that environmental permitting and California Environmental Quality Act compliance be expedited for groundwater cleanup projects so that the cleanup of groundwater can be implemented expeditiously.

> Suggested text changes:
>
> Page 9-23 Line 15: Expedite environmental permitting for implementation of conjunctive management, recharge, <u>groundwater cleanup</u>, and water banking facilities when facility operations increase ecosystem services, and includes predefined benefits/mitigation for wildlife and wildlife habitat.

Page 9-23: Actions that DWR would coordinate are listed with specific dates. The need and purpose of these actions should be clearly identified. Additional resources would likely be needed by DWR to implement these activities and the benefit of these actions should be considered relative to the resources it would require to implement them. For example, the web-based Water PIE would require significant effort for it to be a useful tool.

> Suggested text changes:
>
> Page 9-23 Line 23: *DWR will coordinate with State, federal, tribal, local, and regional agencies to conduct the following activities<u>. DWR will quantify the amount of additional resources needed to implement these activities as well as the expected benefit of these actions for improving management of groundwater in the state.</u>*

Page 9-24 Line 33: Listed actions that deal with developing detailed groundwater basin assessment reports should be focused on groundwater basins without Groundwater Management Plans. It is not clear what value would be provided by creating new reports when local agencies already have characterized groundwater conditions in many areas of the state.

> Suggested text changes:
>
> Page 9-24 Line 33: C. Develop detailed groundwater basin assessment reports by Hydrologic Region and groundwater basin <u>for those basins without adopted Groundwater Management Plans</u>.

Page 9-25 Line 8: The report states 'By January 1, 2015, the Legislature will amend the appropriate code(s) to authorize DWR to evaluate and assess groundwater management and planning, and to develop groundwater management and implementation guidelines.' Basins that have existing management programs that are effective should not be burdened with additional requirements. Any new legislation should recognize that some areas of the state are effectively managing groundwater through local groundwater management agencies and should not place new statewide requirements on such well-managed basins.

> Suggested text changes:
>
> Page 9-25 Line 8: A. By January 1, 2015, the Legislature will amend the appropriate code(s) to authorize DWR to evaluate and assess groundwater management and planning, and to develop groundwater management and implementation guidelines~~.~~ focused on those groundwater basins without adopted Groundwater Management Plans with the recognition that additional regulations for basins that have a history of successful and sustainable management are unnecessary.

Page 9-26 Lines 10-11 – the term 'overdraft' needs to be carefully defined. In many managed groundwater basins, the amount of groundwater storage varies from year to year due to changes in precipitation and other factors. In a well-managed basin, excessive, long-term overdraft is not allowed to occur. How these terms are defined needs to be given careful consideration. Some degree of removal of water from storage is valuable and can be done sustainably if there is a plan to manage overall withdrawals and recharge, the removal of water from storage does not cause adverse environmental impacts, and the removal of water from storage can be reversed if monitoring data indicate adverse impacts are occurring. One of the benefits of removing some water from storage is to allow for more effective conjunctive use of a groundwater basin and surface water supply. By having some storage space available in the groundwater basin, excess surface water supplies can be recharged into the basin when they are available. If there is no storage space available, the opportunity to recharge surface water supplies cannot be readily realized.

> Suggested text changes:
>
> Page 9-26 Line 10: By January 1, 2016, the Legislature will revise the Water Code to i) include disincentives to excessive, long-term overdraft of groundwater basins…

Page 9-26 Lines 38-45: The evaluation of re-operating the state's existing water supply and flood control systems should include flood control facilities owned or operated by the United States Army Corps of Engineers. Existing flood control facilities operated by the Army Corps provide an opportunity for expanded stormwater capture if the dams can be re-operated to temporarily store stormwater. This re-operation can be done in a manner which does not negatively impact flood control measures.

Suggested text changes:

Page 9-26 after line 45 add: <u>This study should include an evaluation of flood control facilities owned or operated by the United State Army Corps of Engineers. These flood control facilities provide an opportunity for expanded stormwater capture if the dams can be re-operated to temporarily store stormwater.</u>

Volume 3 Chapter 16 Groundwater/Aquifer Remediation

Page 16-8 Line 17: Add to the list a recommendation that access to State Revolving Fund (SRF) be expanded to allow funding to be provided to local and regional groundwater management agencies for groundwater contamination cleanup projects. Currently the SRF is only available for cleanup of contamination due to point source discharges. SRF funds should be made available for a broader set of pollutants, such as contamination in groundwater associated with past industrial activities. In addition, state funds should be made available to local groundwater management agencies to remediate contaminated groundwater. Primary responsibility for contamination remediation falls to local groundwater agencies in cases where the responsible parties are unavailable, unable, or unwilling to pay for cleanup. Cleanup becomes more complex and costly when contaminated groundwater migrates beyond the original site of the contamination and negatively impacts groundwater quality over a larger area. One source of funding should be grant funding from the state. Secondly, as stated previously, providing SRF loans to assist local and regional groundwater management agencies in cleanup of groundwater contamination caused by either point sources or nonpoint sources would facilitate cleanup of contaminated sites.

Suggested text to be added:

Page 16-9 add text after line 3 as follows: <u>11. Access to the State Revolving Fund (SRF) should be expanded to allow funding to be provided for local and regional groundwater management agencies to clean up contaminated groundwater, regardless of whether the groundwater contamination originated from point or non-point sources. Currently access to the SRF is only available for cleanup of contamination due to point source discharges.</u>

Page 16-8 Line 17: Add to the list a recommendation that environmental permitting and California Environmental Quality Act compliance be expedited for groundwater cleanup projects so that the cleanup of groundwater can be implemented expeditiously.

Suggested text to be added:

Page 16-9 after Line 3 add: "<u>The state should amend regulations for environmental permitting and California Environmental Quality Act compliance for groundwater cleanup projects so that cleanup projects can be implemented expeditiously.</u>

Volume 3 Chapter 26 Sediment Management

Suggested text changes:

Page 26-5, add text on Line 11-12 as follows: Sediment deposition in the channel or floodplain or <u>behind a dam</u> can decrease flood capacity/flood management.

Page 26-17 before line 1: Add a case study in the section describing a joint project of the U.S. Army Corps of Engineers and the Orange County Water District.

Suggested text to be added:

Page 26-17, before line1 add: <u>A pilot project in the Santa Ana River Watershed is being designed by the U.S. Army Corps of Engineers and the Orange County Water District to manage sediment in the Santa Ana River. The Prado Basin Sediment Management Demonstration Project will remove 500,000 cubic yards of sediment behind Prado Dam and re-entrain the sediment in the river below the dam.</u>

<u>PLACEHOLDER Box 26-? **Case Study: Prado Basin Sediment Management Demonstration Project**</u>

Box 26-? Case Study: Prado Basin Sediment Management Demonstration Project

The Santa Ana River Watershed is the largest in coastal Southern California, covering 2,450 square miles. The Santa Ana River flows 75 miles from headwaters in the San Bernardino Mountains through Orange County to the Pacific Ocean. Upon the completion of Prado Dam in 1941, the sediment transport mechanics of the Santa Ana River watershed were altered dramatically. Ninety-two percent of the watershed drainage flows through the dam. As sediment-laden water enters Prado Basin, the water velocity decreases, sediment settles out of the water and then relatively sediment-free water is released through Prado Dam.

Disruption of natural sediment transport has numerous negative impacts upstream and downstream of the dam. Above the dam, sedimentation reduces the dam's storage and water conservation capacity, threatens infrastructure, and degrades valuable habitat in Prado Basin and along the river upstream of the basin. Downstream of the dam, a lack of sediment in the water released from the dam erodes the river bottom and banks, reduces the infiltration capacity of the river bottom, threatens infrastructure such as bridges and flood control structures, and reduces sand replenishment at beaches.

The U.S. Army Corps of Engineers is partnering with the Orange County Water District (OCWD) on a pilot project to remove up to 500,000 cubic yards of sediment behind the dam and re-entrain the sediment in a controlled manner back into the river downstream. One of the purposes of the Prado Basin Sediment Management Demonstration Project is to provide data, conclusions, and recommendations to design and implement a comprehensive, long-term sediment management program at Prado Basin, which may serve as a model for implementation of similar projects elsewhere. Key issues that will be evaluated at a field scale in the project include sediment removal and conveyance measures, the rate at which sediment can be re-entrained in the river, and potential environmental impacts.

Removal of sediments would restore lost storage capacity behind Prado Dam and enhance water reuse and recharge capabilities. A cooperative agreement between the Corps of Engineers and OCWD allows for the temporary storage of stormwater behind the dam to allow for stored water to be released at rates that enable OCWD to divert stormwater to recharge basins for infiltration into the groundwater basin. Sediment accumulation reduces the volume of available storage. This project has the potential to significantly increase this important water supply for Orange County.

Re-entraining sediments removed from Prado Basin into the river below the dam will allow the sediments to migrate downstream and replenish eroded stream bed sediments and provide sand to beaches and encourage restoration and creation of habitat.

Chapter 4. Flood Management — Table of Contents

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Chapter 4. Flood Management

This resource management strategy (RMS) for flood management is unique to the other strategies in the California Water Plan Update 2013 in that it contains multiple approaches within a single RMS. Flood management is complex and it is still relatively new to the California Water Plan (CWP). For Update 2013, this flood management RMS provides local and regional water managers a broader perspective of the flood management tools that are available and their interrelationships within one chapter. In future CWP updates and as flood management becomes more integrated into the CWP, more than one RMS for flood management could be developed.

This flood management RMS has been subdivided into four approaches:

- Nonstructural.
- Restoration of natural floodplain functions.
- Structural.
- Flood emergency management.

The following sections will discuss flood management in general terms followed by specific subsections related to the four approaches identified above, as necessary.

Flood Management in California

Floods are naturally occurring phenomena in California. Flooding varies according to the diversity of landscape features, climate, and human manipulation of the landscape. Flooding occurs in all regions of California at different times of the year and in different forms. Examples range from tsunamis in coastal areas to alluvial fan flooding at the base of hillsides, and from fast-moving flash floods in desert regions to slow-rise deep flooding in valleys. Flooding can have positive natural impacts, such as keeping erosion and sedimentation in natural equilibrium, replenishing soils, recharging groundwater, filtering impurities, and supporting a variety of riverine and coastal floodplain habitats for some of California's most sensitive species. However, when floods occur where people live and work, they can result in tragic losses of lives and can have devastating economic impacts by damaging critical infrastructure and vital public facilities, taking valuable agricultural land out of production, and endangering California's water supply system.

In traditional flood management, the overarching purpose is to separate flood waters from people and property that could be harmed. In contrast, integrated water management (IWM) seeks a balance between exposure of people and property to flooding, the quality and functioning of ecosystems, the reliability of water supply and water quality, and economic stability including both economic and cultural considerations. This shift changes the focus of flood management from a local to a systemwide context.

One benefit of using IWM is that it encourages a systemwide perspective to solving flood issues as well as an increased understanding of the cause and effect of different management actions. This moves solutions beyond just reducing flood risk resulting from the 100-year flood event to meet the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) requirements to an integrated approach that reduces flood risk and also supports other objectives over a multitude of flood events. Box 4-1 provides the definition of a 100-year floodplain.

PLACEHOLDER Box 4-1 Definition of 100-year Floodplain

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Traditional flood management approaches inadvertently allowed development in floodplains, putting people and property at risk. An IWM approach is balanced and leads to addressing a wide variety of needs. For example, projects are assessed based on the following attributes:

- Potential velocities and timing of flood flows as well as resources that could be disturbed or damaged by those velocities and timings.
- Depth and duration of floodwaters both during the event and after the event.
- Ecosystem processes that could be either enhanced or diminished by projected flows.
- Stability of floodways including potential for scour, erosion, sediment transport, and deposition.
- Opportunities for community and private access and use of lands dedicated to the flood path.
- Alternative or combined uses of the lands that make up the flood path.
- Risks to the community should a flood occur, and recovery capabilities following a flood.
- Water supply implications from the flood management system and operating conditions before, during, and after flood events.

Flood management includes policies and practices related to educating the public, preparing for mitigating damages, responding to and recovering from flooding that creates risk for people and valued resources, as well as protecting the natural and beneficial functions of floodplains to the maximum extent practicable. Traditional approaches to flood management consisted of developing single-purpose flood infrastructure projects, like a dam or a levee, which has resulted in an extensive network of flood infrastructure around the state, including the following:

- More than 20,000 miles of levees.
- More than 1,500 dams.
- More than 1,000 debris basins.
- Many other facilities, including pump stations, monitoring facilities, bypasses, and weirs (California Department of Water Resources 2013).

While this infrastructure has reduced the chance of flooding and avoided damage to lives and property, it has altered and confined natural watercourses. These alterations lead to unintended consequences, such as loss of ecological function and redirection of flood risks upstream or downstream of projects. Additionally, these traditional approaches have encouraged urban and agricultural development within floodplains, which has placed people and property at risk of flooding, as well as degrading wildlife habitat. In 2007, flood legislation was passed in California to enhance statewide understand and address flooding. This legislation is summarized in more detail in Chapter 24, “Land Use Planning and Management” in this volume.

Even with its existing infrastructure, California is at significant risk due to flooding. Further development in flood-prone areas, population growth, and climate change will lead to an increased risk of flooding in the future for people and property. While flood infrastructure can reduce the intensity and frequency of flooding, it cannot completely eliminate the flood risk (i.e., residual flood risk will remain). *California’s Flood Future Report: Recommendations for Managing the State’s Flood Risk* (aka Flood Future Report) (California Department of Water Resources 2013), a companion report to the CWP, characterized the potential for flood exposure in California. More than 7 million people and $580 billion in assets (crops, buildings, and public infrastructure) currently are exposed in the 500-year floodplains in California. A 500-Year Flood has a 1-in-500, or 0.2 percent, probability of occurring in any given year. A detailed description of flood risks in California can be found in the Flood Future Report available at http://www.water.ca.gov/sfmp/ (California Department of Water Resources 2013).

Today, flood management is evolving from narrowly focused traditional approaches toward an IWM approach. The flood management emphasis has shifted to this more integrated approach which includes a mix of multiple measures, including structural and nonstructural approaches. This more integrated approach enhances the ability of undeveloped floodplains and other open spaces to behave more naturally and absorb, store, and slowly release floodwaters during small and medium events. Flood management as part of an IWM approach considers land and water resources on a watershed scale, employing both structural and nonstructural measures to maximize the benefits of floodplains and minimize loss of life and damage to property from flooding, and recognizing the benefits to ecosystems from periodic flooding. Flood management utilizes best management practices, which are methods or techniques that are used in a variety of circumstances and fields, from stormwater management to land use planning, to yield superior results. The application of flood management approaches within the context of an IWM approach extends the range of strategies that could be employed beyond the traditional strategy. Additionally, the strategies that could be implemented to manage flood risk within a hydrologic region or watershed will vary depending on the physical attributes of the area, the presence of undeveloped floodplains, the type of flood hazards (e.g., riverine, alluvial fan, coastal), and the areal extent of flooding.

Although the primary purpose of flood management is public safety (i.e., reduce flood risk and reduce the impacts of flooding on lives and property), approaches to flood management can serve many purposes. Flood management is a key component of an IWM approach. Box 4-2 provides a description of flood management as part of an integrated water management approach.

PLACEHOLDER Box 4-2 Flood Management as Part of an Integrated Water Management Approach

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Flood Governance — Policies and Institutions in California

Traditional flood management resulted in a complex network of agencies with overlapping responsibilities. There are more than 1,300 agencies with some aspect of flood management responsibility in California. These responsibilities include planning, administering, financing, and/or maintaining flood management facilities and emergency response programs. Each agency has unique objectives, authorities, roles, responsibilities, and jurisdictions. Agencies include:

- Local, State, federal, and tribal entities (defined as federally recognized tribes and tribal communities).
- Cities, counties, community service areas and districts.
- Drainage and storm drainage districts.
- Flood control districts.
- Irrigation districts.
- Levee protection districts.
- Joint power authorities.
- Public works districts.
- Public utilities districts.

- Reclamation districts.
- Resource conservation districts.
- Sanitation or sewer districts.
- Special districts.
- Water agencies and departments.
- Water conservation districts.

Almost all communities in California have some measure of responsibility for floodplain management, including adopting National Flood Insurance Rate Maps, conforming to the International Building Code, and enforcing building and land use restrictions.

A number of laws were enacted in 2007 regarding flood risk and land use planning. These laws encourage a comprehensive approach to improving flood management by addressing system deficiencies, improving flood risk information, and encouraging links between land use planning and flood management. Many of the requirements established by these laws are applicable only within the Central Valley.

Below is a summary of the legislation.

- **Senate Bill (SB) 5 (2008) Flood Management** requires DWR and the Central Valley Flood Protection Board (CVFPB) to prepare and adopt a Central Valley Flood Protection Plan (CVFPP) by 2012.
- **Assembly Bill (AB) 156 (2007) Flood Control** provides DWR and the CVFPB with specific authorization that would enhance information regarding the status of flood protection in the Central Valley.
- **AB 70 (2007) Flood Liability** provides that a city or county might be responsible for its reasonable share of property damage caused by a flood if the State liability for property damage has increased due to approval of new development after January 1, 2008.
- **AB 162 (2007) General Plans** requires cities and counties statewide to amend the land use, conservation, safety, and housing elements of their respective general plan to address new flood-related matters.

The DWR FloodSAFE initiative created in 2006 consolidated and coordinated DWR's programs for flood management. Two major milestone reports under the FloodSAFE initiative include the 2012 Central Valley Flood Protection Plan (CVFPP) and the Flood Future Report. The CVFPP, which was adopted in June 2012, proposed a systemwide investment approach for sustainable, integrated flood management in areas currently protected by facilities of the State Plan of Flood Control (SPFC). The Flood Future Report identifies flood management issues statewide and presents recommendations to help address the statewide issues.

Flood Management

Flood management includes a wide range of management actions, which can be grouped into four general approaches: Nonstructural Approaches, Restoration of Natural Floodplain Functions, Structural Approaches, and Emergency Management. These approaches and the management actions within them serve as a toolkit of potential actions that local, State, and federal agencies can use to address flood-related issues and advance IWM.

These actions range from policy or institutional changes to operational and physical changes to flood infrastructure. Such actions are not specific recommendations for implementation; rather, they serve as a suite of generic management tools that can be used individually or combined for specific application situations. A variety of management actions can be bundled together as part of a single flood management project (see Box 4-3 and Box 4-4, Case Study of Flood Management as Part of an IWM Approach). Management actions also can be integrated with other resource management strategies under other objectives (e.g., water supply, water quality, ecosystem restoration, and recreation) to create multi-benefit projects.

PLACEHOLDER Box 4-3 Case Study Number 1 of Flood Management as Part of an IWM Approach

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Several management actions within flood management are considered to be crosscutting (i.e., they would be a part of all resource management strategies). These crosscutting actions are permitting, policy and regulations, and finance and revenue. Volume 1, *The Strategic Plan*, Chapter 7, "Finance Planning Framework" of Update 2013 provides more details on these potential crosscutting actions and Table 4-1 describes how these actions relate to improved flood management.

PLACEHOLDER Table 4-1 Crosscutting Management Actions and Their Relationship to Flood Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Nonstructural Approaches

Nonstructural approaches to flood management include land use planning and floodplain management.

Land Use Planning

Land use planning employs policies, ordinances, and regulations to limit development in flood-prone areas and encourages land uses that are compatible with floodplain functions. This can include policies and regulations that restrict or prohibit development within floodplains, restrict size and placement of structures, prevent new development from providing adverse flood impacts to existing structures, encourage reduction of impervious areas, require floodproofing of buildings, and encourage long-term restoration of streams and floodplains.

Floodplain Management

Floodplain management generally refers to nonstructural actions in floodplains to reduce flood damages and losses. Floodplain management includes:

- **Floodplain mapping and risk assessment.** Floodplain mapping and risk assessment serve a crucial role in identifying properties that are at a high risk of flooding. Communities, State government, and the private sector require accurate, detailed maps to prepare risk assessments, guide development, prepare plans for community economic growth and infrastructure, utilize the natural and beneficial function of floodplains, and protect private and public investments. Development of necessary technical information includes topographic data, hydrology, and hydraulics of streams and rivers, delineation of areas subject to inundation, assessment of properties at risk, and calculation of probabilities of various levels of loss from floods.

- **Land acquisitions and easements.** Land acquisitions and easements can be used to restore or preserve natural floodplain lands and to reduce the damages from flooding by preventing urban development. Land acquisition involves acquiring full fee title ownership of lands from a willing buyer and seller. Easements provide limited-use rights to property owned by others. Flood easements, for example, are purchased from a landowner in exchange for perpetual rights to flood the property periodically when necessary or to prohibit planting certain crops that would impede flood flows. Conservation easements can be used to protect agricultural or wildlife habitat lands from urban development. Both land acquisitions and easements generally involve cooperation with willing landowners. Although acquisition of lands or easements can be expensive, they can reduce the need for structural flood improvements that would otherwise be needed to reduce flood risk. Maintaining agricultural uses and/or adding recreational opportunities where appropriate provide long-term economic benefits to communities and the state.
- **Building codes and floodproofing.** Building codes and floodproofing include specific measures that reduce flood damage and preserve egress routes during high-water events. Building codes are not uniform; they vary across the state based on a variety of factors. Example codes could require floodproofing measures that increase the resilience of buildings through structural changes, elevation, or relocation and the use of flood resistant materials.
- **Retreat.** Retreat is the permanent relocation, abandonment, or demolition of buildings and other structures. Retreat can be used in a variety of settings from floodplains to coastal areas. In coastal regions, this action would allow the shoreline to advance inward and unimpeded in areas subject to high coastal flooding risks, high erosion rates, or future sea level rise. Integrating recreation uses into retreat areas along the shoreline provides economic uses for these buffer lands.
- **Flood insurance.** Flood insurance is provided by the federal government via the NFIP to communities that adopt and enforce an approved floodplain management ordinance to reduce future flood risk. The NFIP enables property owners in participating communities to purchase subsidized insurance as a protection against flood losses. If a community participates in the voluntary Community Rating System and implements certain floodplain management activities, the flood insurance premium rates are discounted to reflect the reduced flood risks.
- **Flood risk awareness (information and education).** Flood risk awareness is critical because it encourages prudent floodplain management. Flood hazard information is a prerequisite for sound education for understanding potential flood risks. If the public and decision-makers understand the potential risks, they can make decisions to reduce risk, increase personal safety, and expedite recovery after floods. Effective risk awareness programs are critical to building support for funding initiatives and to building a connection to the watershed.

PLACEHOLDER Box 4-4 Case Study Number 2 of Flood Management as Part of an IWM Approach

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Restoration of Natural Floodplain Functions

This approach recognizes that periodic flooding of undeveloped lands adjacent to rivers and streams is a natural function and can be a preferred alternative to restricting flood flows to an existing channel. The intent of natural floodplain function restoration is to preserve and/or restore the natural ability of undeveloped floodplains to absorb, hold, and slowly release floodwaters, to enhance ecosystem, and to protect flora and fauna communities. Natural floodplain function conservation and restoration actions can include both structural and nonstructural measures. To permit seasonal inundation of undeveloped floodplains, some structural improvements (e.g., weirs) might be needed to constrain flooding within a defined area along with nonstructural measures to limit development and permitted uses within those areas subject to periodic inundation. Actions that support natural floodplain and ecosystem functions include the following:

- **Promoting natural hydrologic, geomorphic, and ecological processes.** Human activities, including infrastructure such as dams, levees, channel stabilization, and bank protection, have modified natural hydrological processes by changing the extent, frequency, and duration of natural floodplain inundation. These changes disrupt natural geomorphic processes, such as sediment erosion, transport, and deposition, which normally cause channels to migrate, split, and rejoin downstream. These natural geomorphic processes are important drivers that create diverse riverine, riparian, and floodplain habitat to support fish and wildlife, and provide natural storage during flood events. Restoration of these processes might be achieved through setting back levees, restoring channel alignment, removing unnatural hard points within channels, or purchasing lands or easements that are subject to inundation.
- **Protecting and restoring quantity, quality, and connectivity of native floodplain habitats.** In some areas, native habitats and their associated floodplain have been lost, fragmented, and degraded. Lack of linear continuity of riverine, riparian habitats, or wildlife corridors, impacts the movement of wildlife species among habitat patches and results in a lack of diversity, population complexity, and viability. This can lead to native fish and wildlife becoming rare, threatened, or endangered. Creation or enhancement of floodplain habitats can be accomplished through setting back levees and expanding channels or bypasses, or through removal of infrastructure that prevents flood flows from entering floodplains. Coastal wetlands have been severely reduced, resulting in a loss of habitat for freshwater, terrestrial, and marine plant species. Restoration of these habitats could provide a buffer against storm surges and sea level rise.
- **Invasive species reduction.** Invasive species can reduce the effectiveness of flood management facilities by decreasing channel capacity, increasing rate of sedimentation, and increasing maintenance costs. Reductions in the incidence of invasive species can be achieved by defining and prioritizing invasive species of concern, mapping their occurrence using BMPs for control of invasive species, and using native species for restoration projects.

Structural Approaches

Structural approaches to flood management include flood infrastructure, reservoir and floodplain storage and operations, and operations and maintenance (O&M). When local entities are a partner on any federal project, the sponsor has to agree to operation, maintenance, repair, rehabilitation, and replacement (OMRR&R), which goes beyond the requirements of O&M.

Flood Infrastructure

Flood infrastructure varies significantly based on the type of flooding. Flood infrastructure can include:

- **Levees and floodwalls.** Levees and floodwalls are designed to confine flood flows by containing waters of a stream or lake. Levees are an earthen or rock berm constructed parallel to a stream or shore or around a lake to reduce risk from all types of flooding. Levees could be placed close to stream edges, or farther back (e.g., a setback levee). Ring levees could be constructed around a protected area, isolating the area from potential floodwaters.

- **Channels and bypasses.** Channels and bypasses convey floodwaters to reduce the risk of slow-rise, flash, and debris-flow flooding. Channels can be modified by deepening and excavating the channel to increase its capacity, or lining the streambed and/or banks with concrete, riprap, or other materials to increase drainage efficiency. Channel modifications can result in increased erosion downstream, degradation of adjacent wildlife habitat, and often require extensive permitting. Bypasses are structural features that divert a portion of flood flows onto adjacent lands or into underground culverts to provide additional flow-through capacity and/or to store the flows temporarily and slowly release the stored water.
- **Retention and detention basins.** Retention and detention basins are used to collect stormwater runoff and slowly release it at a controlled rate so that downstream areas are not flooded or eroded**.** A detention basin eventually drains all of its water and remains dry between storms. Retention basins have a permanent pool of water and can improve water quality by settling sediments and attached pollutants.
- **Culverts and pipes.** Culverts and pipes are closed conduits used to drain stormwater runoff. Culverts are used to convey streamflow through a road embankment or some other type of flow obstruction. Culverts and pipes allow stormwater to drain underground instead of through open channels and bypasses.
- **Coastal armoring structures, shoreline stabilization, and streambank stabilization.** Coastal armoring structures and shoreline stabilization reduce risk to low-lying coastal areas from flooding**.** Coastal armoring structures are typically massive concrete or earthen structures that keep elevated water levels from flooding interior lowlands and prevent soil from sliding seaward. Shoreline stabilization reduces the amount of wave energy reaching a shore or restricts the loss of beach material to reduce shoreline erosion rates. Types of shoreline stabilization include breakwaters, groins, and natural and artificial reefs. Streambank stabilization protects the banks of streams from erosion by installing riprap, matting, vegetation, or other materials to reduce erosion.
- **Debris mitigation structures.** When debris and alluvial flooding occur, Sabo dams, debris fences, and debris basins separate large debris material from debris flows, or they contain debris flows above a protected area. These structures require regular maintenance to periodically remove and dispose of debris after a flood. Deflection berms or training berms can be used to deflect a debris flow or debris flood away from a development area, allowing debris to be deposited in an area where it would cause minimal damage.

Reservoir and Floodplain Storage and Operations

- **Reservoir and floodplain storage.** These provide an opportunity to regulate flood flows by reducing the magnitude of flood peaks occurring downstream. Many reservoirs are multipurpose and serve a variety of functions including water supply, irrigation, habitat, and flood control. Reservoirs collect and store water behind a dam and release it after the storm event. Floodplain storage occurs when peak flows in a river are diverted to adjacent offstream areas. Floodplain storage can occur naturally when floodwaters overtop a bank and flow into adjacent lands, or storage can be engineered using weirs, berms, or bypasses to direct flows onto adjacent lands.
- **Storage operations.** This optimizes the magnitude and timing of reservoir releases. Storage operations can reduce downstream flooding by optimizing the magnitude or timing of reservoir releases, or through greater coordination of storage operations. Coordination can take the form of formal agreements among separate jurisdictions to revise reservoir release operations based

on advanced weather and hydrology forecasts, or it can simply involve participation in coordination meetings during flood emergencies.

Operations and Maintenance

O&M is a crucial component of flood management. O&M activities can include inspection, vegetation management, sediment removal, management of encroachments and penetrations, repair or rehabilitation of structures, or erosion repairs. Because many flood facilities constructed in the early to mid-20th century are near or have exceeded the end of their expected service lives, adequate maintenance is critical for these facilities to continue functioning properly.

Flood Emergency Management

Flood emergency management includes the following activities:

- **Flood preparedness.** Flood preparedness includes the development of plans and procedures on how to respond to a flood in advance of a flood emergency including preparing emergency response plans, training local response personnel, designating evacuation procedures, conducting exercises to assess readiness, and developing emergency response agreements that address issues of liability and responsibility. Preparing for floods can also include modifying or restricting new development in floodplains, removing existing structures that are the most at risk, and restoring natural floodplains.
- **Emergency response.** Emergency response is the aggregate of all those actions taken by responsible parties at the time of a flood emergency. Early warning of flood events through flood forecasting allows timely notification of responsible authorities so that plans for evacuation of people and property can be implemented. Emergency response includes flood fighting, emergency evacuation, and sheltering. Response begins with, and might be confined to, affected local agencies or operational areas (e.g., counties). Depending upon the intensity of the event and the resources of local responders, response from regional, State, and federal agencies might be required.
- **Post flood recovery.** Flood recovery programs and actions include restoring utility services and public facilities, repairing flood facilities, draining flooded areas, removing debris, and assisting individuals, businesses, and communities to return to normal protect lives and property. Recovery planning could include development of long-term floodplain reconstruction strategies to determine if reconstruction would be allowed in flood-prone areas, or if any existing structures could be removed feasibly. Such planning should review what building standards would be required, how the permit process for planned reconstruction could be improved, funding sources to remove existing structures, natural habitat restoration, and how natural floodplains and ecosystem functions could be incorporated.

Connections to Other Resource Management Strategies

An IWM approach relies on the application of multiple strategies. In addition to the flood-specific strategies, other water resource management strategies included in the Update 2013 have the potential to provide flood management benefits and may be incorporated as an element of an IWM approach.

Resource management strategies that share important synergies with flood management are described briefly below.

- **Land use planning and management.** One of the most effective ways to reduce the vulnerability to potential flooding is through careful land use planning that is fully informed by applicable flood information and flood management practices. Land use policies that encourage locating new development outside floodplains can reduce flood risks. Land use policies that encourage compact development and low-impact development can reduce flood volumes and peaks. In addition, nonstructural approaches to flood management can reduce flood risk to both existing and future development.
- **Sediment management.** Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of a floodplain, the depth and composition of soils, the quality of river habitats, and the type and density of vegetation. Disruption of the dynamics of natural sediment transport can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying capacity of natural channels through increased sedimentation. Sediment is a major component of alluvial fan and debris-flow flooding.
- **Watershed management.** Watersheds are an appropriate organizing unit for managing floodplains. Restoring, sustaining, and enhancing watershed functions are key goals of flood management in the context of IWM.
- **Urban stormwater runoff management.** Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways along with the timing and extent of flooding. Impervious surfaces increase runoff volumes and velocities, which result in streambank erosion and potential flooding problems downstream. Urban runoff can pick up a variety of pollutants from the ground before it enters streams, rivers, and coastal waters. However, watershed approaches to urban runoff management can capture, treat, and use urban runoff for beneficial uses in a manner that mimics a natural hydrologic cycle.
- **Agricultural land stewardship.** Due to flat topography and rich soils caused by historical flood deposits, floodplains are often ideal for agricultural uses. Agricultural runoff can carry pollutants, such as fertilizers, into the water system. However, responsible stewardship of agricultural lands can prevent urban development within floodplains, constraining farming and ranching practices to those areas that are compatible with floodplain management. Innovative funding mechanisms like flood easements can be used to compensate farmers who allow their fields to be flooded during extreme events.
- **Forest management**. Forestry practices can influence not only sediment transport from upland streams, but also the timing and magnitude of peak flows. The high amount of surface roughness in forested floodplains reduces floodwater velocities, spreads flows across a larger area of the floodplain, and attenuates downstream flows. Catastrophic wildfires can increase peak flows and reduce surface water infiltration, which can cause erosion and debris flooding. Forest management to reduce catastrophic wildfires is an important action to minimize flood damages.

Resource management strategies that are also management actions directly contributing to flood management include the following:

- **Conveyance.** Many streams and channels are used to support both flood flow conveyance and water supply conveyance. Improvements to regional water supply conveyance systems could enhance the potential for flood flow conveyance, and vice versa.

- **Surface storage.** Most of California's major surface water reservoirs are managed for multiple purposes including water supply, hydropower, water quality, recreation, and ecosystem needs as well as flood management. Increasing local and regional surface storage has the potential to provide greater water management flexibility for capturing runoff and controlling flood flows.
- **System reoperation.** The primary goal of forecast-coordinated and forecast-based operations is to improve downstream flood protection while improving, or at least not degrading, water supply, environmental, or recreational uses through better hydrologic forecasting and coordinated reservoir operations.
- **Outreach and education.** Regular outreach is needed to educate the public on flooding, flood risks, floodproofing, and impacts of climate change, as well as to explain what households, businesses, and communities can do to reduce or mitigate risk to acceptable levels. Outreach is also needed to educate the public on natural beneficial functions of floodplains.
- **Recycled water.** Storm flows can be captured and used as a recycled water source for a variety of uses. However, the impaired quality of these flows can lead to unintended consequences. For example, irrigation and groundwater recharge with recycled water can lead to damaged foliage, diminished infiltration rates, and increased runoff in some cases.

Resource management strategies that could directly benefit from natural functions of flooding include the following strategies:

- **Ecosystem restoration.** Floodplain environments are dynamic in nature and are highly productive biological communities, given their proximity to water and the presence of fertile soils and nutrients. California native riparian and aquatic animal and plant communities are adapted to conditions of seasonal flooding. Many other terrestrial plants and animals use riparian areas for forage and movement across the landscape. The principal opportunities for improvement in both flood management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains.
- **Pollution prevention.** Floodplains that function well improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion and sedimentation of streams, and moderating temperature fluctuations.
- **Water-dependent recreation.** Protecting and enhancing public access to rivers, lakes, and beaches increases public safety, fosters environmental stewardship, and increases economic sustainability of flood management projects. Flood management infrastructure must be designed to protect public trust uses such as navigation and recreational access to the state's waterways and beaches. Flood protection facilities, natural floodplains, and restored areas can improve recreational access to waterways by providing opportunities for integrating suitable recreation facilities.
- **Recharge area protection, conjunctive management, and groundwater storage.** Diversions of flood flows for groundwater infiltration can reduce downstream flooding and improve water supply by storing groundwater as well as providing water for conjunctive use. The generally flat topography of natural floodplains and the permeable nature of alluvial soils promote infiltration into the subsurface for storage in soils and aquifers.

Potential Benefits

Primary benefits of flood management are derived from the potential to reduce risks to lives and property from flood events and increase flood resilience, which reduces social and economic disruption and flood recovery costs. Flood management also provides beneficial opportunities for water supply, environmental management, water quality, recreation, hydropower, and navigation. Potential benefit categories are discussed briefly in the following subsections. Table 4-2 provides a summary of potential benefits and costs of the specific flood management strategies and management actions.

PLACEHOLDER Table 4-2 Benefits and Costs of Management Actions

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Flood Risk Reduction Benefits

The importance of flood risk reduction to promote public safety and economic stability cannot be understated. More than seven million people and $580 billion in assets (crops, buildings, and public infrastructure) are currently exposed in 500-year floodplains in California (California Department of Water Resources 2013). Many areas in California lack even basic protection from a 100-year flood. Flood management approaches decrease this risk by decreasing the probability of flooding and the consequences from flooding using a wide variety of actions. Flood infrastructure, operations, and maintenance can reduce the frequency, extent, and depth of flooding. Floodplain management and land use planning, building resiliency into the system along with emergency preparedness, response, and recovery, further reduce residual risks that cannot be reduced by infrastructure alone. Limiting development in floodplains helps address the primary source of flood risk instead of merely addressing its symptoms. Without these flood risk-reduction benefits, a major flood has the potential to allow millions of citizens, homes, businesses, and agricultural lands to be flooded, cause critical infrastructure to go out of service for long periods of time, and cause isolation or closure of vital services.

Integrated Water Management Benefits

An IWM approach is a crosscutting benefit that bundles management actions based on systemwide needs. Flood management as part of an integrated approach can leverage flood management benefits from a variety of projects and programs, including those focused on other forms of water resources management. There are several cost advantages of an IWM approach due to improved delivery and implementation of flood management. Improved agency interaction through an IWM approach is at the core of implementing these advantages because a diverse set of stakeholders must coordinate, cooperate, and collaborate to develop successful IWM projects. Improved agency interaction also facilitates effective planning, agency alignment, and identification of investment priorities and funding. A key benefit of agency alignment for flood management is reduced permitting and mitigation process costs as well as improving governance and policy.

Agency alignment at all levels (local, State, and federal agencies as well as tribal entities) also enables statewide planning to be completed that helps identify governance and policy needs required to develop statewide investment priorities. Setting statewide investment priorities encourages development of integrated projects and increases the pool of available funding, making funding more reliable. Local, State, and federal agencies and tribal entities are beginning to structure their flood management programs to support multiple-benefit projects. These multiple-benefit projects have access to different or new funding sources. Partnering with other agencies can increase flexibility for pursuing diverse funding sources to overcome grant caps and varied eligibility requirements. Coordination across geographic and agency boundaries can help agencies pool and leverage their funding to make the best use of limited human and financial resources.

Water Supply Benefits

An integrated approach to flood management would maximize the beneficial uses of water to improve water supply reliability, stormwater management, and groundwater recharge. An IWM approach to flood management would increase water supply reliability by improving the operational flexibility of multipurpose infrastructure, such as channels and bypasses, that are used for water supply and floodwater conveyance, and multipurpose reservoirs to store floodwaters that are used later for water supply. The restoration of natural floodplain functions by reconnecting streams to their historical floodplains, setting back levees, creating floodplain storage, and acquiring easements would encourage natural groundwater recharge by providing an expansive area where floodwaters would slow in velocity, disperse over a broader area, and infiltrate into the ground.

Environmental Benefits

An integrated approach to flood management would enhance ecosystems by restoring the natural hydrologic, geomorphic, and ecologic processes and by improving the quantity, quality, and connectivity of riverine and coastal habitats. These actions result in healthier, self-sustaining ecosystems that provide breeding and feeding grounds for a wide variety of aquatic and terrestrial species. Such actions also help maintain the diversity of plants and animals by aiding in the recovery of endangered and threatened species, and controlling invasive species. These actions also increase ecosystem resiliency to uncertain changing conditions such as climate change. Integrating ecosystem conservation and restoration with flood risk-reduction projects is an essential component of flood management that can increase effectiveness, sustainability, and public support. Restoration of natural floodplain functions to attenuate peak flows would include benefits to natural watershed.

Water Quality Benefits

Restoration of natural floodplain functions as part of a flood management strategy would improve water quality by filtering nutrients and impurities from runoff, which reduces levels of pathogens and toxic substances. Restored natural floodplain functions would help process organic wastes, control erosion and sedimentation by stabilizing banks, and moderate temperature fluctuations by planting trees to provide shade. Infrastructure, such as debris mitigation structures, can improve water quality by reducing the amount of sediment from debris flooding.

Recreation Benefits

Integration of flood management and recreation can increase the number and quality of recreational areas and parks for water-oriented sports, boating, swimming, hiking, and camping. Floodplain management through land use planning and ecosystem restoration can support recreational activities by providing areas of active- and passive-use recreation in floodplains and flood greenways, increasing open space, and increasing scenic value. Even in urban areas, establishing greenways as part of flood management projects and replacing concrete channels with more natural creek environments can satisfy recreation demand. Recreation provides communities with economic and public health benefits while supporting the economic, environmental, and social sustainability of flood management projects.

Hydropower Benefits

California's major surface water reservoirs that are intended for flood management generate hydropower or are hydraulically connected to reservoirs that generate hydropower. Optimizing storage operations provides more water management flexibility to achieve multiple benefits, including hydropower generation.

Navigation Benefits

Several channels and bypasses in California that are subject to flooding provide navigation benefits when used for interstate commerce. Channel dredging operations to increase channel capacity can also provide navigation benefits.

Potential Costs

Since Update 2009, DWR has worked to identify the costs of improving flood management on a statewide basis. Included in this effort are the CVFPP, the Flood Future Report, and regional flood management through integrated regional water management (IRWM) plans. Collectively, these efforts identified the immediate need for more than $50 billion to complete flood management improvements and projects. These flood management projects include maintenance projects and other identified actions. The Flood Future Report also indicated the need for substantial additional funding to complete flood risk assessments throughout the state, and to conduct flood management improvements based on those assessments. Therefore, the total estimated capital investment needed for flood management projects could easily top $100 billion (California Department of Water Resources 2013). These estimates do not include the broader regional economic impacts or ripple effects of flooding, such as the costs resulting from rerouting traffic and closing businesses, and from compromised services of water and wastewater treatment plants, as well as critical facilities such as hospitals. These losses of function have a wider impact that can range from regional to statewide, nationwide, or even international. For example, if flood damages disrupted the delivery of water for a significant amount of time, the economic impacts would be substantial, with the impacts reaching far beyond California. Specifically, if water supply were disrupted in the Delta, impacts would affect not only agricultural production, but also commercial businesses in the San Francisco Bay Area and Southern California.

The costs of different management actions vary significantly. For example, developing a new reservoir can cost billions of dollars, but some policy and regulatory management actions can be implemented for minimal investments of time and money. IWM projects can sometimes cost more in advance to implement. However, thoughtful planning can leverage different funding streams and provide multiple benefits over the project’s useful life, sometimes reducing overall project costs. In addition to the initial costs for an action, provisions must be made for long-term operations and maintenance (O&M). Costs for implementing a single management action can also vary widely based on quantity, location, real estate costs, permitting and mitigation costs, and other factors. Therefore, potential costs for flood management actions are summarized qualitatively in Table 4-2. Initial and annual costs for each management action were characterized with a low, medium, or high value, which represents the relative cost of the management action compared to other flood management actions.

Nonstructural measures, such as land use planning and floodplain management, are some of the most cost-effective strategies for reducing flood risk over the short and long term. It is more economical to invest in information and education efforts that help keep people and property out of floodplains than to invest in flood infrastructure. Constructing flood infrastructure requires significant up-front capital investment and long-term funding for operations and maintenance.

Multiple benefit projects often have higher initial costs than narrowly focused projects, which can sometimes be a barrier to their implementation. However, an IWM project can achieve economies of scale while meeting multiple resource management goals with less cost and a smaller footprint. An integrated approach can also leverage flood management benefits from a variety of projects and programs, including those focused on other forms of water resources management.

Higher initial and short-term costs of IWM projects can be offset sometimes by benefits that accrue time. For example, setting back a levee to reconnect the channel with the floodplain and promoting natural floodplain functions can have higher initial costs than a fix-in-place levee improvement. However, incorporating the setback levee can decrease project delays as well as reduce regulatory compliance, long-term operations, maintenance, and repair costs. Setback levees can also provide long-term benefits to water supply and the environment by increasing groundwater infiltration and providing habitat restoration opportunities.

Climate Change Considerations and Implications

Climate change will have a significant impact on the timing and magnitude of precipitation and runoff and contribute to a rise in sea levels. Increased air temperatures will result in more precipitation falling as rain rather than snow, contributing to increases in winter runoff. While future precipitation is somewhat uncertain, greater flood magnitudes are anticipated due to more frequent atmospheric river storms and other extreme weather events (Dettinger 2011). In addition, rising sea levels could increase the potential for high tides and storm surges to inundate low-lying coastal areas. Warmer temperatures and changes in soil moisture are expected to contribute to more frequent and intense wildfires. Areas damaged by these wildfires would have a greater potential for flooding associated with accelerated runoff and debris flows. Such changes could affect the magnitude and frequency of flood events, although specific effects would be difficult to predict reliably.

Understanding the specific effects of climate change is a significant data gap. For example, much of the current analysis of climate and water impacts considers how changes in various mean conditions (e.g., mean temperatures, average precipitation patterns, mean sea level) will affect water resources, particularly California's water supply. Although many water resource factors are affected by such average conditions, some of the most important impacts, including flooding, will result not from changes in averages, but from changes in local extreme precipitation and runoff events over short periods (California Department of Water Resources 2006). These extremes are difficult to predict because climate projections from global climate models have difficulty representing regional- and local-scale precipitation patterns and processes that drive extreme events over short time steps (e.g., hours or days). Without this information, flood planners and emergency managers have a difficult task making informed decisions about the impacts and risks of climate change.

Adaptation

The impacts of climate change can be addressed through adaptation and mitigation measures. Anticipated changes in runoff, frequency and magnitude of flood events, and sea level rise present serious challenges to flood management. However, many of the approaches presented in the flood management actions, such as setback levees, reservoir operations, floodplain management, land acquisition/easements, retreat, and restoring ecosystem functions, can assist in providing more flexibility and resiliency in adapting to a changing climate. For example, levee setbacks and bypasses can provide greater protection from anticipated changes in the timing and magnitude of precipitation and runoff, as well as changes in storm intensities that are expected by improving flow capacity.

Incorporating climate change considerations into land use and emergency management planning decisions can also play a key role in flood management. For example, decisions to avoid developing in areas particularly vulnerable to sea level rise or retreating from them would greatly reduce the risk of flooding and/or the need for new or larger levees, seawalls, coastal armoring, or other flood infrastructure.

Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Structural approaches to flood risk management are often the most energy-intensive actions that cause increased greenhouse gas emissions from the building and maintenance of infrastructure. In contrast, nonstructural approaches, such as land use planning and floodplain management, require less energy and emit fewer greenhouse gas emissions. Floodplain restoration can also aid in mitigating climate change through carbon sequestration in soil and vegetation or riparian restoration.

Major Implementation Issues

Major issues and challenges to implementing flood management as part of an IWM approach were identified in the Flood Future Report, based upon interviews with more than 140 local, State, and federal agencies, and tribal entities, with varying levels of flood management responsibilities in each county. Additional issues have been identified by land use and environmental planners, and others with flood management responsibility. Together, these issues represent the following primary barriers related to implementation of flood management in the context of IWM:

- Issue 1: Inadequate and unstable funding and incentives.
- Issue 2: Inadequate data/information and inconsistent tools.
- Issue 3: Inadequate public and policymaker awareness of flood risk.
- Issue 4: Complex and fragmented governance structure impeding agency alignment and systems approach (California Department of Water Resources 2013).

Issue 1: Inadequate and Unstable Funding and Incentives

Current funding for flood management is inadequate and unreliable because it is dependent upon agency user fees, assessments, bond funding, and earmarking. Flood management program funding has been cyclical, often increasing following a flood disaster, then gradually decreasing as other priorities garner the attention of residents and policymakers. Local funding is linked to city and county revenue and is affected by changes in the state’s economy. State funding has been heavily dependent on bond funds, and to some extent the fluctuations of the General Fund. Funding of flood management for local agencies is hampered by Propositions 13 and 218, which restrict an agency’s ability to increase property assessments. Funding from assessments or impact fees can have limitations on where the funds can be spent geographically. For example, upstream infrastructure that decreases downstream risk could not be funded in a flood management assessment district because the infrastructure is not within the district’s geographic boundary. Flood management budgets are especially susceptible to reductions in dry years or economic downturns. State bond funding will be depleted by 2017, and the federal spending on flood management is uncertain, but is unlikely to continue at the same levels as in the past.

Funding for flood management, as well as funding for an IWM approach, is inadequate to meet current needs. Funding sources and incentives have changed over time. In addition, agencies involved in flood management do not have clear and strong incentives from State and federal governments to implement regional/systemwide planning and multi-benefit solutions. Financial incentives provided to local agencies traditionally have not distinguished between supporting narrow-purpose projects implemented by a single agency and multi-benefit projects implemented on a regional scale. Providing adequate incentives for an IWM approach to flood management is important because it requires investments of time, energy, and staff resources for the required coordination to achieve long-term benefits.

Also, new regulations place additional requirements on projects. For example, the California Water Code Sections 12840-12842 stipulate that “recreational development should be among the purposes of all federal flood control and watershed protection projects.” This regulation requires broad-based public funding of recreational opportunities associated with many types of flood control projects. As with the Davis-Dolwig Act, the State has struggled to establish a funding strategy to provide for planning, construction, operation, and maintenance of these facilities to “achieve the full utilization of such projects for recreational purposes.”

Issue 2: Inadequate Data/Information and Inconsistent Tools

Improved quantity, quality, and accessibility of data are needed in large areas of the state to close data gaps related to flood risk, floodplain mapping, hydrologic data, flood infrastructure integrity, ecosystem mapping, flood forecasting, flood readiness, and climate change.

Inadequate and outdated hydrologic and mapping data hinder assessments of flood risk across the state. Accurate and detailed mapping is needed to guide development, prepare plans for community economic growth and infrastructure, utilize natural and beneficial functions of floodplains, and protect private and public investments. The condition of aging infrastructure is sometimes not fully understood and can be expensive to assess. Funding is often inadequate to meet current data, assessment, and mapping needs.

A need also exists to increase the quality of environmental information and tools for informing flood management and conservation activities. Even in cases where data and information are available, variable conditions, such as climate change, add new uncertainties to existing data sets. Although much information is available online about flood management including data, case studies, budget information, funding sources, climate change, and other planning tools, many data repositories have differing levels of accessibility, ease of use, and metadata requirements. Although these data exist, the sources are difficult to locate and access and data may be inconsistent.

Other major data gaps exist that inhibit a consistent methodology to assess flood risk and measure project benefits. Different methods are used across the state to assess flood risk, which yields inconsistent results. The methods include those used by the United States Army Corps of Engineers (USACE), FEMA, and local agencies. Each of these methods were developed to reach unique objectives that required different levels of complexity. For example, FEMA uses an approach that has traditionally focused on hazards associated with 100-year and 500-year flood events, in contrast to USACE approach that assesses and describes risk in terms of expected annual damage (EAD). Many of the benefits that are reaped using an IWM approach cannot be quantified monetarily, which hampers assessing and comparing different integrated solutions. It is especially difficult to assign a value to ecosystem restoration benefits. No set methodology exists to measure such benefits, resulting in an under-valuation of the benefits of IWM.

Issue 3: Inadequate Public and Policymaker Awareness and Understanding of Flood Risk

Policymakers and the public have varying levels of understanding about risks and consequences of flooding. Lack of awareness and understanding can increase risks to people and property and make it difficult to achieve sustainable, long-term planning and investment that supports flood management. Currently, many California residents and policymakers are primarily aware of risk of flooding based on the need to purchase flood insurance under FEMA's NFIP. This program and the use the of terms 100-year and 500-year floods, leads many people to mistakenly believe that protection from a 100-year flood means that their home will not be flooded for 100 years. Actually, a 500-year flood has a 1-in-500 probability of occurring in any given year (0.2 percent annual chance) and a 100-year flood has a 1-in-100 probability of occurring in any given year (1 percent annual chance). These flood event levels indicate a percentage of probability and severity, but they do not mean that such a flood would happen only once every 100 or 500 years. Policymakers need updated data, including maps, to help make better decisions. Also, residents and policymakers rely on the infallibility of flood infrastructure, including levees, and are often unaware of consequences that occur outside floodplains (e.g., economic impacts, loss of critical services).

Another barrier to understanding is that flood risk is a dynamic and complex topic because it is impacted by changes in hydrology (including climate change uncertainties), reliability of the data used to assess flood hazards, reliability of flood management structures, and changes in the consequences of a flood event. Changes in any of these factors can greatly change a community's flood risk over time.

In addition, major floods are infrequent, they occur many years apart, and this results in the public underestimating flood risk. Policymakers responsible for land use decisions need updated information and data from the State and FEMA in order to make better decisions that avoid putting people and assets at risk. This lack of awareness makes it difficult to achieve sustainable, long-term planning and investment that support flood management and even more difficult to gain public understanding of flood risks.

Issue 4: Complex and Fragmented Governance Structure Impeding Agency Alignment and Systems Approach

Responsibilities for flood management are currently fragmented across numerous local, State, and federal agencies and tribal entities. Flood management is often complicated by the large number of agencies and entities involved, and by their complex jurisdictional roles and responsibilities. More than 1,300 agencies have some aspect of flood management responsibility in California. Each of these agencies has unique objectives, authorities, roles, responsibilities, and jurisdictions. The fragmentation of flood management responsibilities results in poor agency alignment. Overlapping jurisdictions and conflicting missions and priorities across various local, State, and federal agencies and tribal entities involved in flood management can lead to inconsistent policies, regulations, enforcement, and practices. Coordinating activities within this fragmented jurisdictional landscape can be challenging, particularly for local entities. There is a strong need for improved agency alignment through coordination of policies and guidance across multiple agencies at all levels – local, State, federal, and tribal.

The complex and fragmented governance structure in California hinders and sometimes precludes agency alignment. Agency alignment is cooperation and collaboration toward a common IWM approach. There are agency coordination issues that are both intragency and interagency, as well as coordination with regulatory and resource agencies. Improper agency alignment results in projects that are narrowly focused, miss opportunities for integration and funding maximization, and projects that have unintended negative impacts on downstream or upstream communities and natural environments. Most flood management agencies in California understand the benefits of an IWM approach, but might not have the authority or resources to participate in projects that are regional or systemwide in scale.

Another consequence of improper agency alignment is inconsistent regulatory requirements, permitting processes, and enforcement practices. Unclear, conflicting, or mutually exclusive regulatory objectives or requirements can increase costs and time needed for regulatory review. Lack of consistent standards for mitigation requirements can impede project development and implementation. This can result in conflicts between competing project objectives.

Agency alignment is essential for establishing clear roles and responsibilities related to emergency preparedness, response, and recovery. This lack of alignment, as well as concerns about funding and cost reimbursement, can result in confusion or inaction during a flood emergency.

Recommendations

Recommendations to facilitate implementation of flood management initiatives have been developed in response to the four major issues identified above. These recommendations are organized by the need to: Pursue stable funding and create incentives.

- Develop and disseminate adequate data and tools.
- Improve public and policymaker awareness and understanding of flood risk.
- Strengthen agency alignment.

Pursue Stable Funding and Create Incentives

1. **Federal and State agencies should link funding to using an IWM approach by 2017**. Providing incentives for an IWM approach with State and federal funds will encourage local agencies to implement higher-value, multi-benefit projects when developing options for flood management. This effort could include providing incentives to all agencies and tribal interests for regional- or systemwide-scale flood management planning that encompasses conservation and restoration, including riverine, floodplains, and other ecosystem functions. Performing planning at this broader scale for flood management enables a more holistic approach to water and ecosystem management. Future flood management planning and actions should proceed utilizing an IWM approach. Flood management planning based on IWM leads to better projects, reduces the need for more costly structural solutions, and promotes multiple societal benefits, including public safety, environmental stewardship, and economic stability.
2. **Local, State, and federal agencies should work together to develop a roundtable to assess the applicability of all potential funding sources, propose new funding options, and identify needed changes to legislation by 2020**. The roundtable initially would review existing funding sources identified in the online resource catalog of flood management funding created by State and federal agencies, review other funding mechanisms, and make recommendations. The roundtable should also propose changes or alterations to local funding

restrictions by pursuing exemptions to existing statutes for public safety. For example, changes to current laws (e.g., Proposition 218) could include reclassification of flood management agencies as exempted public safety utilities. The roundtable also could pursue establishment of regional assessment districts.

3. **By 2017, State and federal agencies should expand processes for developing, funding, and implementing flood management projects with an IWM approach in each region.**. The use of IWM would promote and encourage incorporation of project components that achieve a broader range of objectives. Also, this would result in development of a common terminology for State and federal programs to help grantors and grant recipients understand IWM processes.
4. **By 2020, DWR should add compliance with best management practices and other statuary requirements for land use as a criterion for making flood management funding decisions.** Land use policies that keep new development out of floodplains and encourage compact, low-impact development can reduce costs of flood management projects.
5. **By 2017**, **working with the California Emergency Management Agency (CalEMA) and other State agencies, DWR should provide grant funding for increased coordination among flood responders, facility managers, planners, tribal entities, and representatives of State and federal resource agencies to improve flood emergency preparedness**. Coordination before a flood event improves emergency preparedness by identifying and reinforcing areas of expertise, available resources, and agreement about plans.
6. **State and federal agencies should establish more stable sources of funding to assist local and regional collaboration, including IRWM.**
7. **By 2020, the State should develop broad-based public funding to support recreational facility planning, construction, and O&M in flood protection projects as required by California Water Code Sections 12840-12842.**

Develop and Disseminate Adequate Data and Tools

8. **DWR should ensure that guidelines, tools, and technical assistance for an IWM approach include best management practices for flood management by 2017**. Improved guidelines and technical assistance would provide tools and incentives for local implementation.
9. **DWR should provide technical assistance to local flood management agencies that encourage an IWM approach.** Improved guidelines and technical assistance would provide tools and incentives for local implementation.
10. **Local, State, and federal agencies should work together to develop methodologies and data to perform regional risk assessments across the state by 2020.** These efforts will provide flood management agencies at all levels with the data and tools necessary to establish and achieve appropriate levels of flood protection. Goals should be based on the number of lives and value of property at risk, degree of urbanization, number of critical facilities, type of flood, and level of acceptable risk for the region.
11. **DWR, academic institutions, USACE, U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) should build on studies currently underway to develop a climate change report by 2017.** The report would focus on climate change and its impacts on flood hydrology, concentrating on local extreme events instead of average precipitation and temperature changes. Such a report would be valuable because it would provide additional localized information to the State and would address water and flood-related issues that will be affected by climate change, understanding that flooding is impacted more by extreme events and that potential future impacts might be more severe.

12. **By 2017, DWR should catalog, provide, and promote online information and resources about flood risk, grants, and other related topics in a comprehensive statewide database.** DWR should develop a comprehensive statewide database on flood management that builds on and enhances existing efforts. The database should be accessible to flood management agencies and tribal entities. The database should include:
    A. Natural floodplain resources.
    B. Land use and watershed boundaries.
    C. Updated flood hazard areas.
    D. Floodplain mapping.
    E. Risk maps.
    F. Flood awareness information.
    G. Hydrologic, geomorphic, and climate change data and information.
    H. Relevant ecosystem information.
    I. Other relevant information.

    Easy access to data, case studies, budget information, and planning tools will improve local agency capabilities to identify opportunities for collaboration and integration. Additionally, online information resources should lead to an increase in the public's overall flood risk awareness.
13. **DWR should update the Flood Future Report by 2017 and every five years thereafter. The update should cover**:
    A. Risk assessment information.
    B. Regional planning efforts including prioritized projects.
    C. Flood readiness.
    D. Flood awareness initiatives.
    E. Land use decision-making.
    F. Agency alignment efforts in the context of IWM.
    G. Flood-related funding needs.
    H. Discussion of revisions to the recommendations to improve flood management.
14. **With input for local agencies, State and federal agencies should develop a methodology, including indicators and metrics, for evaluating regional or systemwide benefits by 2017.** The methodology should quantify benefits, such as ecosystem restoration, recreation and open space, water supply, groundwater recharge, sustainability, and community/social benefits.
15. **By 2017, local, State, and federal agencies should identify data and forecasting needs, including cost estimates, for emergency management.** Accurate and timely forecasts for flood events can increase warning time, save lives, and reduce property damage. Additional data will help improve the readiness and response to floods. Providing data and tools to improve system operations will improve overall management of natural and human-made flood systems.
16. **By 2017, DWR should release the next update of the Central Valley Flood Protection Plan.** Updates to the CVFPP will be prepared by DWR and its partner agencies (including USACE, the Central Valley Flood Protection Board, and local agencies) every five years, following adoption of the first CVFPP by the Central Valley Flood Protection Board in 2012.

Improve Public and Policymaker Awareness and Understanding of Flood Risk

17. **By 2017, DWR should develop and disseminate educational outreach materials targeted for local governments and the public that clearly explain flood risks and measures that**

can reduce these risks. Materials should include explanations of urban levels of flood protection, the limited role of FEMA 100-year floodplain maps, the role of the 2007 flood legislation, and types of actions for flood risk-reduction actions that are available to communities (nonstructural, natural floodplain function restoration, structural approaches, and emergency management).

18. **By 2017, DWR, in collaboration with local governments and organizations that represent flood management and land use professionals, should be developing land use planning principles and criteria that will help local planning agencies and decision-makers in conducting prudent land use planning**. These principles should be promoted as best management practices to increase prudent land use planning. These principles should promote preservation of existing floodplains and restoration of natural floodplain functions, where feasible. The planning principles should recognize unique differences of rural, suburban, and urban California. These best management practices should include definition of the philosophy to "minimize adverse environmental impact" for project planning.
19. **By 2017, local, State, and federal agencies and tribal entities should establish processes to leverage existing flood management awareness initiatives, data, and share outreach programs tools, templates, and other resource materials to local agencies**.

Strengthen Agency Alignment

20. **Local, State, and federal agencies should pursue a regional permitting process to avoid limitations of compensatory mitigation, allow more landscape restoration opportunities, and facilitate more efficient permitting processes for project execution**.
21. **By 2017, local, State, and federal agencies should develop a plan to conduct regular flood emergency preparedness and response exercises statewide and increase participation among public agencies at all levels in flood fight training.** Regular training, tabletop drills, and participation in training and functional exercises are a necessary part of disaster preparedness.
22. **By 2015, local, State, and federal agencies should work together to identify regional flood planning areas.** Flood management planning areas are needed throughout the state with boundaries that are systemwide, watershed-based where feasible, and consistent with existing federal and State agency boundaries, including existing IRWM funding areas and existing CWP planning areas. By organizing regional planning areas hydrologically, these areas would be better able to address issues that impact a united group of stakeholders. Also, such areas would enable the complex array of flood management agencies to begin working together to resolve common issues on a regional basis.
23. **By 2020, State and federal agencies should realign existing internal processes to support regional groups that undertake regional flood planning by addressing statutes that impede this realignment.** State and federal agencies can modify internal agency processes and programs that would assist local agencies in expediting project delivery and promoting multi-benefit projects. This effort should include the development of common terminology for State and federal programs, which would help agencies communicate the various aspects and benefits of multiple-objective projects, as well as remove the statutes that impede agency alignment.
24. **By 2017, resource agencies should collaborate to develop a permitting guidebook that includes a description of relevant permits, permit applications, and permitting guidance.** The guidance would include a description of the types of permits that are required for flood management projects and guidelines for when such permits are needed, explicit lists of what

information permitting agencies require to issue these permits, and explanations of how and when to coordinate with regulatory agencies for project-specific and regional permitting approaches.

25. **By 2017, when issuing permits for flood facility maintenance or improvement projects, resource agencies should give priority to those projects where immediate action is needed and to those projects that provide the greatest long-term benefits to protect lives, property, and sensitive habitats.** Resource agencies should jointly develop regulatory guidance for issuing regional permits for flood control/stormwater conveyance maintenance or improvement activities, including consistent mitigation requirements for such projects. Resource agencies should develop guidance for expedited processes and/or appropriate exemptions, based on the California Environmental Quality Act, for emergency flood management activities and for flood control facility improvement projects that have minor wetland impacts.

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Table 4-1 Crosscutting Management Actions and Their Relationship to Flood Management

Management action	Description
Permitting	Regional and programmatic permitting methods can provide faster and better delivery of flood management activities including operations, maintenance, repair, habitat enhancement and restoration, and minor infrastructure improvement or construction projects. Regional and programmatic permitting methods can be used to manage permitting needs collectively for multiple projects, over longer planning horizons, while consolidating mitigation and conservation efforts into larger, more viable conservation areas. This can accelerate permitting of flood system projects and lower per-unit costs versus project-by-project mitigation. Regional and programmatic permitting methods include regional Habitat Conservation Plans, Natural Community Conservation Plans, programmatic Endangered Species Act Section 7 consultations, and Regional General Permits.
Policy and regulations	Policies and regulations that clarify flood management roles and responsibilities for local, regional, state, and federal agencies can help improve coordination across the large number of agencies and entities involved in flood management. Multiple jurisdictional and regional partnerships can be encouraged for flood planning and flood management activities including permitting, financing, operation and maintenance, repair, and restoration.
Finance and revenue	Several finance and revenue strategies can increase the ability to fund flood management projects. Aligning flood management projects with other existing or planned projects (such as roads or highways) leverages funding from different agencies and jurisdictions to help accomplish objectives. Consolidating projects on a regional or watershed level can also improve cost effectiveness and financial feasibility by pooling resources.

Table 4-2 Benefits and Costs of Management Actions

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs [a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Non-structural approaches								
Land use planning	Addresses all types of flooding. Reduces risk by reducing what is flooded. No reduction in residual risk.	X	X	X	X			Low initial costs. No significant change to annual costs.
Floodplain management								
Floodplain mapping and risk assessments	Addresses all types of flooding. Could reduce flood risk if risk assessment leads to land use decisions that are consistent with floodplain mapping data.							Low initial costs. Low to medium annual costs.
Land acquisitions and easements	Addresses all types of flooding. Reduces risk by reducing what is flooded. No redirected hydraulic impacts or reduction in residual risk.	X	X	X	X			High initial costs based on location, extent, or type of easement. Costs include real estate acquisitions, relocations, mitigation, engineering, and permitting. Annual costs vary.
Building codes and flood proofing	Addresses all types of flooding. Reduces what is flooded and the susceptibility of people and property from harmful flooding. Reduces residual risk.							Low initial costs for building code changes and costs for implementation could be recovered through additional fees. Medium to high initial costs for flood proofing depending on number of structures.
Retreat	Addresses coastal flooding by reducing what is flooded and the susceptibility of people and property from harmful flooding. Reduces residual risk.		X	X				Medium to high initial costs depending on type of retreat, location, extent, type of structure, real estate acquisitions, mitigation, and permitting.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs [a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Flood insurance	Addresses all types of flooding. Improves the recovery of people and property from harmful flooding. Reduces residual risk.							Low to medium initial costs. Low annual costs.
Flood risk awareness – information and education	Addresses all types of flooding. Does not directly reduce flood risk, but reduces what might be flooded if it leads to land use decisions that are consistent with floodplain function. Reduces residual risk.							Low initial costs. Low to medium annual costs depending on extent of training and how flood information is disseminated.
Natural floodplain function restoration								
Natural floodplain function Natural hydrologic, geomorphic, and ecological processes	Addresses all types of flooding. Can reduce peak flood flows and decrease the frequency, extent, and depth of flooding. No change in residual risk.	X	X	X	X			Medium to high initial costs based on size of project, real estate acquisitions, relocations, permitting, design, construction, mitigation, and loss of property taxes. Annual O&M costs could increase during establishment period, but would be reduced over long-term.
Quantity, quality, and connectivity of native floodplain habitats	Does not directly reduce flood risk. Can provide mitigation opportunities for habitat losses elsewhere for flood management. No changes in residual risk.	X	X	X	X			Highly variable initial costs depending on type of effort, real estate acquisitions, relocations, permitting, design, construction, and potential loss of property taxes. Annual costs could increase short term, but would decrease long term.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs [a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Invasive Species	Addresses all types of flooding. Reduces the probability, extent, and depth of flooding by decreasing channel capacity and increasing rate of sedimentation.		X	X				Medium initial costs with potential costs related to permitting, maintenance, mapping, and technical evaluation on how to control invasive species. Annual maintenance costs would increase slightly.
Structural approaches								
Flood infrastructure								
Levees and floodwalls	Addresses all types of flooding by reducing the frequency of flooding. Reduces the susceptibility of people and property from harmful flooding. If development is encouraged behind levees, residual risk would increase.	[b]	[b]	X				High initial costs depending on location, number of levees or floodwalls, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Channels and bypasses	Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding.	X	X	X			X	High initial costs depending on location, number of channels or bypasses, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Retention and detention basins	Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding.	X			X			High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Culverts and pipes	Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding.							High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Coastal armoring structures, shoreline, and streambank stabilization	Addresses coastal flooding by reducing the frequency of flooding and reducing erosion rate. Reduces the susceptibility of people and property from harmful flooding. If development is encouraged behind armoring structures and		[c]	[c]				High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs [a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
	shoreline stabilization, residual risk would increase.							
Debris mitigation structures	Addresses debris and alluvial fan flooding by retaining debris and reducing downstream flooding. Reduces the susceptibility of people and property from harmful flooding.				X			Medium-high initial costs. High annual O&M costs for debris removal and disposal.
Reservoir and floodplain storage and operations								
Reservoir and Floodplain Storage	Addresses slow-rise and flash flooding. Reduces the probability, extent, and depth of flooding. Reduces frequency of flooding and residual risk by reducing peak flows.	X	X	X		X		Medium to very high initial costs depending on location and size of storage, real estate acquisitions, relocations, permitting/mitigation costs, complexity of facilities. Additional small annual O&M costs.
Storage Operations	Addresses slow-rise and flash flooding by reducing frequency and magnitude of downstream flooding and reducing residual risk. Reduces the probability, extent, and depth of flooding. Coordinated operations can involve transfer of risk, increasing risk in one area, while decreasing risk in another.	X	X	X		X		Low-medium initial costs depending on location, extent of facilities, forecasting and hydrologic technology used. Annual costs are variable.
Operations and maintenance	Addresses all types of flooding. Reduces vulnerability of flood infrastructure. No change in residual risk.		X				[d]	Low initial costs. Medium to high annual costs depending on type and extent of maintenance.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs [a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Flood emergency management								
Flood preparedness	Addresses all types of flooding. Reduces the susceptibility of people and property from harmful flooding. Reduces residual risk by reducing the consequences of flooding.							Low to medium initial costs. Low annual costs.
Emergency response and flood fighting	Addresses all types of flooding. Reduces the susceptibility of people and property from harmful flooding. Reduces residual risk by reducing the consequences of flooding							Low to medium initial costs. Low annual costs.
Post-flood recovery	Addresses all types of flooding. Does not directly reduce flood risk, but improves public safety in the aftermath of a disaster.							Low to medium initial costs. Low annual costs.

Notes:

[a] The costs defined in this table are in relative terms. No actual number value can be placed on the costs due to the site-specific nature of the management actions. The terms low, medium, and high are used to give a comparison between the management actions and not for budgetary or costing purposes.

[b] Setback levees

[c] Natural and artificial reefs

[d] Dredging

PLACEHOLDER Box 4-1 Definition of 100-year Floodplain

[box to come]

Box 4-2 Flood Management as Part of an Integrated Water Management Approach

IWM is an approach that combines specific flood management, water supply, and ecosystem actions to deliver multiple benefits. An IWM approach uses a collection of tools, plans, and actions to achieve efficient and sustainable solutions for the beneficial uses of water. An IWM approach reinforces the interrelation of different water management components — such as water supply reliability, flood management, and environmental stewardship — with the understanding that changes in the management of one component will affect the others. This approach applied to flood management looks at the benefits of flooding to natural systems. IWM acknowledges the importance and function of flooding as a natural part of the ecosystem and helps people to learn to live with and better understand the benefits of flooding. This approach promotes system flexibility and resiliency to accommodate changing conditions such as regional preferences, ecosystem needs, climate change, flood or drought events or financing capabilities.

An IWM approach requires unprecedented alignment and cooperation among public agencies, tribal entities, land owners, interest-based groups, and other stakeholders. It is not a one-time activity but rather an ongoing process. Also, this approach relies on blending knowledge from a variety of disciplines including engineering, planning, economics, environmental science, public policy, and public information.

An IWM approach represents the future of flood management in California with the goal to improve public safety, foster environmental stewardship, and support economic stability.

Box 4-3 Case Study Number 1 of Flood Management as Part of an IWM Approach

An example of a flood related IWM project is the Lower Carmel River Floodplain Restoration and Flood Control Project. The project area is located at a dynamic interface between marine and freshwater systems and serves as a refuge for sensitive species. The agencies involved in this project are the Big Sur Land Trust, Monterey County Water Resources Agency, Monterey County Public Works Department, and California State Parks. The project was developed to:

- Improve hydrologic functions by reconnecting floodplains through levee setback or removal and land restoration.
- Integrate storage and filtration basins into restored floodplains to increase flood flow retention, promote sediment and nutrient removal, and increase groundwater recharge.
- Conduct geotechnical engineering analyses and hydraulic modeling needed to support design of flood control improvements.
- Modify placement and/or size of existing levees and/or floodwalls, add new levees or floodwalls, construct new bypasses, and restore channel form and function to improve flood protection.
- Develop local flood management plan updates.
- Establish and preserve agricultural operations adjacent to, but hydrologically disconnected from the floodplains.

Project benefits include reduced damage to residences and commercial businesses as well as local and state infrastructure, improved connectivity between the main channel and overbank areas to reduce flooding hazards, installation of a protective buffer against sea level changes, and restored riparian and wetland habitat within the historical floodplain.

Box 4-4 Case Study Number 2 of Flood Management as Part of an IWM Approach

An example of a flood related IWM project is the flood management, habitat restoration and recharge project on the San Diego River. The project is located in Lakeside in San Diego County and is within a 580-acre area known as the Upper San Diego River Improvement Project. Improvements to the San Diego River and adjacent lands are focused on flood management, environmental habitat restoration, recreation, and water supply.

This project consists of project components that:

- Improve flood management and water quality as a result of restoration efforts designed to increase the wetlands, improve circulation in the pond, and improve sediment transport.
- Acquire ownership or land tenure on property for preservation or restoration purposes.
- Restore riparian habitat types for several threatened and endangered species.
- Restore the channel including work to improve flood management, restore natural meanders, and lower the 100-year flood level by widening the floodway.
- Implement low-impact development techniques including the use of bioswales to capture and treat urban runoff and improve water quality.
- Capture flood flows for habitat (wetland) enhancement and for groundwater recharge.

Benefits of the project include:

- Reduced flood levels.
- Prevention of urban development in a floodplain, currently subject to development pressure.
- Improved sediment balance.
- Protection of downstream bridges and water pipeline.
- Improved water quality via constructed wetlands to treat urban runoff.
- Increased water supply through groundwater recharge of the aquifer.
- Increased recreation and public access opportunities including camping areas, trails, and a boardwalk in the pond. with access for the disabled

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Chapter 9. Conjunctive Management and Groundwater Storage

Introduction

Conjunctive management or conjunctive use refers to the coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies in a region to meet various management objectives. Surface water and groundwater resources typically differ significantly in their availability, quality, management needs, and development and use costs. Managing both resources together, rather than in isolation, allows water managers to use the advantages of both resources for maximum benefit. Conjunctive management thus involves the efficient use of both resources through the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin that is planned to be used later by intentionally recharging the basin when excess water supply is available, for example, during years of above-average surface water supply or through the use of recycled water. The necessity and benefit of conjunctive water management are apparent when surface water and groundwater are hydraulically connected. Well-planned conjunctive management that prevents groundwater depletion by maintaining baseflow to streams and support for ecosystem services not only increases the reliability and the overall amount of water supply in a region, but also provides other benefits such as flood management, environmental water use, and water quality improvement.

In this document, the two terms - conjunctive water management and conjunctive water use are utilized to depict the same water management strategy described above. However, there are water management practitioners who distinguish between the two or view them somewhat differently. Examples of definitions of the terms as used by other practitioners are furnished in Box 9-1.

PLACEHOLDER Box 9-1 Examples of Definitions of Conjunctive Water Management and Conjunctive Water Use

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Conjunctive management can occur at multiple spatial scales – from local to regional to statewide scale. As the spatial scale increases, so do the difficulties of and benefits derived from implementing conjunctive management projects. Locally planned conjunctive management projects are easier to design and implement and should be an integral part of water management portfolios of local agencies. At the larger geographic scale, conjunctive management with an appropriate infrastructure and applied in a responsible manner has the potential to span multiple regions and achieve greater benefits than individual, isolated projects. In the long run, failure to integrate surface water and groundwater management across jurisdictions will make it difficult to manage water for multiple benefits and to provide for sustainable use including the ability to identify and protect or mitigate potential impacts on third parties, ensure protection of legal rights of water users, establish rights to use vacant aquifer space and banked water, reduce subsidence potential of aquifers, protect the environment, recognize and protect groundwater recharge and discharge areas, and safeguard natural resources under the public trust doctrine.

Project Feasibility Considerations

One of the roles and goals of California is to seek statewide water supply reliability and sustainability. Similarly, one of the roles and goals of the California Department of Water Resources (DWR) is to strive for sustainable groundwater supplies throughout the state. Conjunctive management is emerging as one major water resources management tools to attain these goals. The five project feasibility considerations of conjunctive management are:

- <u>Hydrogeologic feasibility:</u> Hydrogeologic feasibility takes into consideration the hydrogeologic constraints that must be identified.
    - Where is the recharge zone for the aquifer that is going to be pumped?
    - What is the mechanism and rate of recharge?
    - Is the recharge zone connected to the aquifer that is going to be pumped?
    - What are the soil, sub-soil, and aquifer characteristics – infiltration capacity, porosity, hydraulic conductivity, specific yield – that are important for success of conjunctive management?
- <u>Available groundwater storage capacity:</u> Available groundwater storage capacity denotes the space available to recharge the basin.
- <u>Water source:</u> Water source provides the supply of water that will be used to store water in the groundwater system. Water sources include imported water, local runoff, and treated wastewater.
- <u>Conveyance:</u> Conveyance is necessary to transport the water from water source to recharge location and to distribute water from the groundwater extraction facility to the point of demand. Conveyance systems include lined and unlined canals, pipelines, and streams.
- <u>Recharge and extraction and pre- and post-treatment facilities:</u> Recharge and extraction and pre- and post-treatment facilities are essential components to complete the conjunctive management project. Recharge includes direct spreading, injection, in-lieu recharge, and induced natural recharge. Extraction may be for direct use, pump back to conveyance systems, and surface water exchange.

The five project feasibility considerations of conjunctive management — hydrogeologic feasibility, available groundwater storage capacity, water source, conveyance, recharge and extraction and pre- and post-treatment facilities — are the fundamental, physical elements that are indispensable for conjunctive management to be functional. If any of these physical elements are missing, it will make conjunctive management impractical and unworkable.

Project Development Components

In practical terms, once the five project feasibility considerations are determined to be satisfactory, a set of five project development components must blend together for a specific conjunctive management project or program:

- <u>Groundwater planning and management:</u> Groundwater planning is the process to decide what needs to be accomplished to preserve the natural resource. The outcome of this planning process is a groundwater management plan. Groundwater management denotes the set of activities that direct how to implement management actions identified during the planning step as contained in the groundwater management plan. Formally speaking, groundwater management is the planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource. Groundwater management aims to improve specific aspects of the management of groundwater resources in individual basins or portions of basins across a region or throughout the state. The improvements pertain to many aspects of groundwater management, including characterizing and increasing knowledge of individual groundwater basins, identifying basin management strategies or objectives, planning and conducting groundwater studies, and designing and constructing conjunctive management projects.

- Project construction and operation: Project construction and operation may include construction and operation of treatment facilities, conveyance facilities, or spreading basins as well as installation and operation of monitoring, production, and injection wells, and drilling of test holes.
- Institutional structures: As with other types of projects, conjunctive management projects must also adhere to local ordinances in addition to State and federal laws and regulations. Institutional structures include
    - Laws.
    - Regulations and ordinances.
    - Contracts and agreements.
    - Political support.
    - Public-private partnerships.
    - Governance.
- Funding: Funding sources include State and federal grants and loans, State and local bonds, State and local taxes, assessments, and fees, and public-private partnerships. As with other types of projects, a conjunctive management project also has associated cost components, and financing and economics issues. As a result, available sources of funding have to be identified and secured to successfully plan, design, and implement a conjunctive management project.
- Organizational capacity building: Organizational capacity building is the process of equipping entities, usually public agencies, with certain skills or competences, or upgrading performance capability by providing assistance, funding, resources, and training. This is important for the continued operation and long-term success of conjunctive management projects.

The five project development components - groundwater planning and management, project construction and operation, institutional structures, funding, and organizational capacity building - bring a conjunctive management project to Fruition.

Figure 9-1 presents in a nutshell, practical considerations that need to be thought about and met before planning conjunctive management projects and important components for implementing successful conjunctive management projects.

PLACEHOLDER Figure 9-1 Conjunctive Management - Project Feasibility and Development

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Groundwater Storage

Understanding terms related to groundwater storage is critical to ensure the success of a conjunctive management project. Groundwater in storage or simply groundwater storage can be defined as the quantity of water found at a given time in the pore spaces of the alluvium, soil, or rock formation beneath the land surface. Groundwater storage capacity — the maximum attainable groundwater storage — is defined as the maximum volume of usable void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin. Available groundwater storage capacity is defined as the volume of usable physical space available at a given time to store water in the pore spaces of the alluvium, soil, or rock formation beneath the land surface. These water-filled geologic materials, or aquifers, may receive the water (and be recharged or replenished) from natural hydrologic processes, or the water may be introduced to the aquifer by active groundwater management. The water in these aquifers may be withdrawn through wells, or the water may discharge naturally, contributing to streamflow or to the supply of water for springs, seeps, and wetlands.

Groundwater remains an important water source for municipal drinking water, agriculture, and individual water users across California. Groundwater is also a vital source of flow in many streams, providing support for aquatic and riparian habitat. Benefits of groundwater storage, as compared to surface water storage, include smaller evaporation loss, lower susceptibility to adverse impacts from natural and human induced hazards, and less maintenance costs. Over the years, groundwater has played a leading role in transforming California into the nation's top agricultural producer, most populous state, and the eighth largest economy in the world.

According to the California Department of Public Health (CDPH), an estimated 30 million Californians, more than three quarters of the state's population, receives at least part of their drinking water from groundwater. Groundwater from either private domestic wells or other groundwater-dependent supplies not regulated by the State provides drinking water to an additional one to two million people (State Water Resources Control Board 2012; Department of Water Resources 2013a). Many small- to moderate-sized towns and cities (e.g., Fresno, Davis, and Lodi) rely solely on groundwater for their drinking water supplies. Statewide, about six million people rely 100% on groundwater (State Water Resources Control Board 2013). In California, public water supply systems alone use about 13,000 wells to supply water to the public (California Department of Water Resources 2013b). The demand on groundwater will continue to increase as California's population grows from 38 million in 2012 to a projected 51 million by 2050, based on current trends (California Department of Water Resources 2013c). The increased demand on groundwater has caused significant groundwater depletion in many locations, which needs to be recognized and addressed to ensure sustainability of this important resource. To obtain a quantitative feel of the importance of groundwater to California water supply, see Box 9-2.

PLACEHOLDER Box 9-2 Importance of Groundwater to California Water Supply

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Groundwater and Surface Water Interrelated

In the past, water resources in many regions have been developed and managed with the underlying assumption that surface water and groundwater are separate resources. Although for a number of basins in California, there has been an intuitive understanding of the interrelationship between surface water and groundwater, only in recent years have water scientists, planners, and managers unmistakably recognized that the extraction and use of one resource affects the other. Groundwater and surface water bodies are connected physically in the hydrologic cycle and interact with each other. At some locations or at certain times of the year, groundwater will be recharged through infiltration from the bed of a stream. At other locations or at other times, groundwater may discharge to the stream, contributing to its baseflow. Similarly, degradation of surface water quality may result in a corresponding degradation of groundwater quality. Pollution of groundwater may result in a corresponding pollution of surface water. Thus, changes in either the groundwater or surface water system will directly affect the other. Although this physical interconnection is understood in general terms, details of the physical, chemical, and residence time relationships remain the topic of a number current studies for certain basins by various State and federal agencies. Effective conjunctive management acknowledges the interconnection of the two resources and requires proper characterization of local and regional interconnections to ensure safety and effectiveness for specific programs and projects and to maximize the beneficial uses of the integrated water system (see Box 9-3).

PLACEHOLDER Box 9-3 Groundwater and Surface Water, a Single Source

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Meeting Multiple Objectives

Conjunctive water management projects may be implemented to meet many objectives including improving local or regional water supply reliability, increasing flood protection, meeting environmental needs, improving groundwater quality, countering land subsidence, or reducing groundwater overdraft. One example of conjunctive water management is recharging groundwater storage using surface water when additional surface water supplies are available and affordable. The surface water may be introduced into the aquifer through injection wells, spreading the water on permeable ground surfaces in recharge ponds, or introducing the water into streams that are connected to the aquifer through permeable streambeds. The stored water in the aquifer can then be withdrawn at a later time when surface water is not available or too expensive to meet local demands. In some areas, recharge may be accomplished by providing surface water to users who would normally use groundwater (also called in-lieu recharge), thereby leaving more groundwater in place for restoring groundwater levels or for later use. For further discussion on natural and managed (also called artificial or intentional) groundwater recharge, see Box 9-4.

PLACEHOLDER Box 9-4 Groundwater Recharge: Natural and Managed

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

A sustainable conjunctive water management program consists of several components that include investigating the groundwater aquifer characteristics, estimating surface water and groundwater responses, and appropriate monitoring of groundwater level and quality. In addition, reliable institutional systems for ensuring environmental compliance, providing long-term system maintenance, and managing contractual and legal features of the program are critical to sustainability. An important issue pertaining to legal features of a conjunctive water management program is addressing who actually owns the artificially recharged water in a managed recharge project, particularly if the timing of recharge has prevented natural recharge, which would belong to all the overlying landowners. The major legal issue is how to resolve the ownership/extraction rights related to water that has been artificially added into a multi-jurisdictional/multi-land owner groundwater basin. The question is whether the water that has been artificially added to a groundwater basin is the property of the entity that added it or, once it commingles with the existing groundwater, does it become groundwater governed by the prevailing statutes in the California Water Code? A legal and scientific way of settling the issue of extraction rights would be an inescapably important factor in the public discussion of conjunctive management and groundwater storage.

Conjunctive management and groundwater storage is closely linked with other resource management strategies such as groundwater remediation/aquifer remediation and recharge area protection. Groundwater remediation may be implemented in areas where the usability of the aquifer for groundwater storage has been compromised by aquifer contamination, thereby partially or fully restoring the capacity of the aquifer for storage or limiting the extent of the water quality problem.

Although conjunctive management programs often involve artificial recharge of aquifers with water from other sources, most California aquifers and therefore any conjunctive management programs using those aquifers, are heavily dependent on recharge from natural sources. As such, the resource management strategy for recharge area protection is critical to maintaining groundwater storage for long-term reliability of conjunctive management supplies.

Conjunctive management and groundwater storage, in the context of Integrated Regional Water Management (IRWM), may be intertwined with many other management strategies, including conveyance, desalination, drinking water treatment and distribution, ecosystem restoration, floodplain management, recycled municipal water, surface storage, urban land use management, water transfers, system reoperation, and watershed management. Examples of these relationships are discussed in this chapter and elsewhere in Update 2013.

Chronicle of Conjunctive Management and Groundwater Storage in California

Conjunctive management has been practiced in California to varying degrees since the Spanish mission era (1770s – 1830s). The first known managed (artificial or intentional) recharge of groundwater in California occurred in Southern California during the late 1800s, and managed recharge has become an increasingly important part of integrated water management in many areas.

Unlike surface water use, groundwater use in California does not have a statewide management program or statutory permitting process. When the Water Commission Act became effective in 1914, surface water appropriative rights became subject to a statutory permitting process. The statutory permitting process is defined under California law, which stipulates that a water user must obtain, modify, or renew water rights permits from the State Water Resources Control Board (SWRCB). The Water Commission Act of 1914 was the predecessor to today's California Water Code statutes governing appropriation. In addition to surface water, groundwater classified as underflow of a surface water system, a "subterranean stream flowing through a known and definite channel," was also made subject to the statutory permitting process. However, most groundwater in California is presumed to be "percolating water," that is, water in underground basins and groundwater that has escaped from streams and is not subject to a permitting process. As a result, most of the body of law governing groundwater use in California today has evolved through a series of court decisions beginning in early 20th century (California Department of Water Resources 2003).

The California Legislature has repeatedly held that groundwater management is a local responsibility (Sax 2002). The State's role is to provide technical and financial assistance to local agencies and work with them for planning and implementing groundwater management efforts. There are three forms of groundwater management in California: local agency management, local groundwater ordinance, and court adjudication (California Department of Water Resources 2003).

More than 20 types of local agencies are authorized by statute to provide water for various beneficial uses. Many of these agencies also have statutory authority to institute some form of groundwater management, but their specific authority related to groundwater management varies. In 1991, Assembly Bill (AB) 255 authorized local agencies overlying basins that are subject to critical conditions of overdraft, as defined in DWR's Bulletin 118-80, to establish voluntary groundwater management plans within their service areas (California Department of Water Resources 2003).

The passage of AB 3030 in 1992 (California Water Code Section 10750 et seq.) greatly encouraged local agencies to adopt groundwater management plans for managing their groundwater resources whether or not the groundwater basin is in overdraft condition. In 2002, the Legislature passed Senate Bill (SB) 1938, which contained new requirements for local agency groundwater management plans and required adoption of these plans for groundwater projects to be eligible for public funds. At the time Bulletin 118-2003 was published in 2003, more than 200 local agencies had adopted AB 3030 groundwater management plans. An additional bill, AB 359, passed in 2011, 1) requires local groundwater agencies, as a condition of receiving State funds for groundwater projects, to include a map identifying groundwater recharge areas in their basins in groundwater management plans and to provide the recharge area maps to local planning agencies and, 2) includes additional local agency reporting requirements, including submittal of groundwater management plans to DWR.

With the emphasis in recent years on integrated regional water planning and management, IRWM plans have been prepared for many regions throughout the state, and the portion of the state covered by an IRWM plan is continually expanding as new IRWM plans are developed. In 2009, DWR went through a Region Acceptance Process (RAP) to accept regions into the IRWM Grant Program. As of the second round of RAP, there are a total 48 IRWM regions, two of which are conditionally approved (see http://www.water.ca.gov/irwm/grants/docs/ResourcesLinks/GraphicFiles/IRWM_E_48_Regions_Merged_Template_11082012.pdf).

An important consideration in the coordination of surface water and groundwater resources is the question of potential adjudications of water rights by tribal communities. Additionally, tribal rights to groundwater in some areas could be significant, for example, in San Diego County. Tribal water rights and adjudications, pertaining to both surface water and groundwater, are issues that must be substantively addressed for viable, long-term water resources planning in California.

Over the past few years, voters and the Legislature have provided significant funding to local agencies for improving water supply reliability and groundwater management. Proposition 13, approved by voters in 2000, provided $200 million for grants for feasibility studies, project design and the construction of conjunctive use facilities, and $30 million for loans for local agency acquisition and construction of groundwater recharge facilities and grants for feasibility studies of groundwater recharge projects. AB 303, enacted in 2000, created the Local Groundwater Assistance (LGA) fund and authorized grants totaling $38.5 million from 2001 to 2009 to help local agencies develop better groundwater management strategies to ensure the safe production, quality, and storage of groundwater.

Proposition 50, passed in 2002, and provided $500 million for IRWM projects. Although this funding is not specifically targeted for groundwater projects, many of the projects in the regional proposals would expand groundwater storage, desalt brackish groundwater, or improve groundwater quality to make new supplies available. Proposition 84, approved in 2006, and provided an additional $1 billion for IRWM projects.

Along with providing increased funding for IRWM projects as noted above, in 2009, the Legislature, as part of a larger package of water-related bills, passed Senate Bill 7x 6 (SBX7 6), requiring that groundwater elevation data be collected in a systematic manner on a statewide basis and be made readily and widely available to the public. DWR was charged with administering the program, which was later named the California Statewide Groundwater Elevation Monitoring or CASGEM Program. The program is voluntary, although future eligibility of State grant funding for associated agencies could be affected if they choose not to participate. Monitoring outside of the state's 515 alluvial groundwater basins and subbasins listed in DWR Bulletin 118-2003 is not required. SBX7 6 provides that:

- Local agencies, counties, and associations interested in volunteering to become Monitoring Entities shall notify DWR by January 1, 2011.
- DWR shall review prospective Monitoring Entity notifications and determine designated Monitoring Entities for each basin and subbasin.
- DWR shall work cooperatively with local Monitoring Entities to achieve monitoring programs that demonstrate seasonal and long-term trends in groundwater elevations.
- Monitoring Entities shall begin groundwater elevation monitoring in fall 2011 and report elevations to DWR by January 1, 2012.
- DWR shall make these groundwater elevation data widely and readily available to the public.
- DWR will perform groundwater elevation monitoring in basins where no local party has agreed to perform the monitoring functions.
- If local parties (for example, counties) do not volunteer to perform the groundwater monitoring functions and DWR assumes those functions, then those parties may become ineligible for water grants or loans from the State.
- DWR shall report findings to the governor and Legislature by January 1, 2012.
- DWR shall report findings to the governor and Legislature thereafter in years ending in five and zero.

As specified in SBX7 6, DWR has established a statewide groundwater elevation monitoring and reporting program. The following list provides the milestones of the CASGEM program achieved through 2012:

- DWR successfully conducted outreach to develop local support throughout the state.
- DWR developed the CASGEM Web site (http://www.water.ca.gov/groundwater/casgem/) and documents to provide easily accessible, up-to-date program information, and technical support.
- Local agencies, counties, and associations volunteered to become CASGEM Monitoring Entities and notified DWR.
- DWR reviewed the submitted notifications and designated Monitoring Entities for several groundwater basins and subbasins throughout the state.

- DWR worked cooperatively with local Monitoring Entities to develop groundwater elevation monitoring programs for their defined monitoring areas.
- DWR developed an online system for a monitoring plan, well information, and groundwater elevation data submittal, which provided public access to this information and data in both tabular and map formats.
- Monitoring Entities began groundwater elevation monitoring and submitting groundwater elevation data to the CASGEM Online System in fall 2011.
- DWR released the CASGEM Online System to the public in mid-November 2011, allowing access to submitted groundwater elevations.
- DWR released the first report of findings of the CASGEM program to the governor and Legislature in January 2012.

On January 1, 2012, Assembly Bill 1152 made revisions to the California Water Code related to the CASGEM Program, which include adding a new Monitoring Entity category, allowing alternative monitoring of groundwater basins, and removing the requirement for DWR to seek concurrence of the State Mining and Geology Board regarding adequacy of monitoring plans to demonstrate seasonal and long-term trends in groundwater elevations.

Data Collection and Management

Statewide data are important in planning and developing the conjunctive water management strategies. The data should include, in addition to those collected as part of the CASGEM Program, groundwater management-related information, groundwater quantity and quality, and water use in the state. DWR's Bulletin 118 series, titled *California's Groundwater*, provides information about the state's groundwater resources and its current resource management practices. Bulletin 118 was last updated in 2003, and unfortunately, it appears unlikely that there will be future funding to continue to update this bulletin. However, without having access to reliable data and analysis on groundwater, the goal to manage this resource better will likely remain unattainable. To respond to this need, as part of Update 2013, DWR has initiated a process to enhance groundwater content in a major way. The objective is to "expand information about statewide and regional groundwater conditions to better inform groundwater management actions and policies through compilation and summarization of data and analysis." This effort will not solve all the statewide and regional issues related to groundwater, but it is intended as a starting point to bring all the available information together from a statewide and regional perspective. The information content on groundwater built through this initiative is anticipated to set the stage for future California Water Plan updates and related activities to provide on a long-term basis additional data, information, and analyses as well as policy needs for California's groundwater planning and management. The major proposed deliverables planned for Update 2013 include the following:

- Consolidated groundwater information from various State, federal, regional, and local water resource planning initiatives.
- Status of regional groundwater conditions, management activities, and problem areas.
- Data gaps to inform future groundwater monitoring needs and activities better.
- Estimates of regional annual change in groundwater storage.
- Illustration of successes and challenges of local and regional management of groundwater through case studies.
- Inventory and potential for conjunctive management of groundwater with other supplies.
- Inventory and potential for groundwater banking and integrated flood management.

- Preliminary indicators to assess groundwater sustainability.

The data and analyses resulting from the above deliverables were consolidated into a report, *California's Groundwater – Update 2013*, that is available online in *Update 2013 Volume 4, Reference Guide*. The information also provided groundwater related contents for *Update 2013 Volume 1, The Strategic Plan and* Volume *2, The Regional Reports*.

The Integrated Water Resources Information System (IWRIS), released by DWR in 2008, is the first centralized water data management system developed to help local and regional water management entities integrate and analyze existing data about their groundwater system and potential value of current groundwater management in their integrated planning processes. It serves as a centralized information system for accessing the data about groundwater as well as groundwater management and some DWR grant program funding statewide. Figure 9-2, generated from DWR IWRIS, shows a distribution of the AB 303 Grants from 2001 to 2008 for helping the development of groundwater management plans which in recent times often include conjunctive management as an important strategy for managing groundwater. Due to a lack of funding, the future of IWRIS remains uncertain. Fortunately, DWR has undertaken a project, Water Planning Information Exchange (Water PIE) that may subsume IWRIS. The ultimate goal of Water PIE is collecting and sharing data and networking existing databases and Web sites using GIS software to improve analytical capabilities and developing timely surveys of statewide land use, water use, and estimates of future implementation of resource management strategies. Phase I of Water PIE has been initiated, which is intended to develop the business and technical requirements for the web-based system. In Phase 2 of Water PIE, a pilot application will be conducted to assess the developed system and refine requirements and design before full implementation commences.

PLACEHOLDER Figure 9-2 Distribution of the AB 303 Grants from 2001 to 2008

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Although the groundwater elevation monitoring provisions of the CASGEM Program are steps in the right direction, there is no comprehensive statewide data-monitoring network for planning and implementing conjunctive management. The availability of information is increasing as local and regional water management entities analyze the existing and potential value of active groundwater management in their integrated planning processes. It is important to have updated information on the various conjunctive water management planning and implementation activities statewide to achieve better coordination among future conjunctive water management planning activities and to avoid potential conflicts. DWR has started developing a statewide inventory of conjunctive management agencies and projects that is included in Update 2013. Detailed information on the inventory is available online in *Update 2013 Volume 4, Reference Guide – California's Groundwater Update 2013*. This initial effort in Update 2013 was not as successful as intended because of the reluctance of local and regional water agencies to release data to build such an inventory. The reluctance of these agencies to provide information emanated primarily from an apprehension about uncertainty in State regulations pertaining to groundwater recharge. This inventory will continue to be updated, refined, and expanded in future California Water Plan updates.

This resource management strategy chapter deals with general and statewide issues associated with conjunctive water management. Issues specific to individual hydrologic regions are discussed in their respective regional reports in *Update 2013 Volume 2, The Regional Reports*. However, for general illustrative purposes, two case studies — one from Southern California and one from Northern California — are provided in Box 9-5 and Box 9-6.

PLACEHOLDER Box 9-5 Conjunctive Management Case Study 1 in Southern California

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 9-6 Conjunctive Management Case Study 2 in Northern California

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

As noted, conjunctive management and groundwater storage is considered an integral element of IRWM, and it is actively promoted and supported by the State. In the context of the rapidly evolving IRWM effort in California, the issue of cooperative arrangement among regional water partners is gaining momentum. Box 9-7 provides a brief description of the Four County Program in Northern California initiated to promote cooperation among participating counties for resolving regional water management issues across jurisdictional boundaries. The Four County Program eventually expanded and added two additional counties to the group and formed the Northern Sacramento Valley Integrated Regional Water Management group. Cooperative agreements such as this can serve as a model of how legal constraints and issues related to regional water management, including conjunctive management projects, may be resolved.

PLACEHOLDER Box 9-7 Regional Cooperative Arrangements in Northern California

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Potential Benefits

Conjunctive management is used to improve water supply reliability and sustainability, to reduce groundwater overdraft and land subsidence, to protect water quality, and to improve environmental conditions. Overdraft is defined as the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions (California Department of Water Resources 2003). Overdraft may cause land subsidence and damage to the environment and increase energy cost in pumping. An example illuminating the beneficial outcome of conjunctive water management in ameliorating groundwater overdraft is included in Box 9-8.

PLACEHOLDER Box 9-8 Groundwater Overdraft and Conjunctive Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Potential benefits from conjunctive management are highly dependent on how well the surface water and groundwater are managed as a single source to adapt to the climate system to maximize use of the water in the managed area. Effective conjunctive management should optimize capture of excess water when it is available so that enough water is stored to meet beneficial use needs while providing a sufficient reserve to get through extended dry periods. However, the benefit derived from effective conjunctive management is limited by the combined, current surface water and groundwater production capacity of the management area.

The climate in California can usually be described as consisting of a wet season and a dry season in a water year. Most water (as rainfall and snow) is in the northern part of the state while most people live in the southern part. However, climate varies greatly over the state. Successful conjunctive water management must recognize the climate variability in California and maximize the use of water throughout the state.

Any conjunctive management strategy will produce changes to the water system. A sustainable conjunctive management strategy should optimize the beneficial and efficient use of the water in the system while balancing all of the objectives. Because of the uncertainty in water demand resulting from population growth, land use changes, and climate change, risk management and opportunity costs should be considered in conjunctive management planning. A good conjunctive management computer-aided tool can help identify and quantify the benefit and potential risk associated with conjunctive management projects. This tool can be considered one element of an overall robust, adaptive water management system for dealing with future uncertainties and provide safe, responsive, and effective oversight. Unfortunately, no such tool currently exists and developing such a tool is one of the recommendations made to improve conjunctive management, included at the end of this chapter.

Table 9-1 lists some of the many potential benefits of conjunctive management and highlights some of the major constraints that influence the usefulness and level of benefit that might be obtained. Example 1 in Table 9-1 can be used anywhere in the state to adapt to the two-season pattern so that more water can be captured in the wet season for beneficial use. Example 2 recognizes the fact of the relatively wet northern part of the state and shows the benefit of using groundwater storage in the reoperation of the State Water Project (SWP) and the Central Valley Project (CVP) to capture more flood flows, provide flood control benefits, and improve water supply availability and reliability. An example of the magnitude and frequency of variability in California's hydrology is furnished in Figure 2-1 of Update 2013 *Volume 1, The Strategic Plan*, Chapter 3, "California Water Today," Figures such those can be used as a guide for identifying the relatively wet areas in the state. Example 3 demonstrates a way of utilizing groundwater that could be used for agricultural production to urban water use to relieve drought emergencies and to provide induced groundwater recharge. Example 4 shows use of surface water for preventing salt water intrusion in coastal areas. Example 5 provides not only a solution to reduce or contain the flood risks resulting from the increased runoff due to urbanization, but also to maintain the natural groundwater recharge in the project areas and provide opportunity for treating storm water in detention ponds.

PLACEHOLDER Table 9-1 Potential Benefits of Conjunctive Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Currently conjunctive management in Southern California provides more than 2.5 maf of average annual water supply (Montgomery Watson and Water Education Foundation 2000). Conservative estimates of additional implementation of conjunctive management indicate the potential to increase average annual water deliveries throughout the state by 0.5 maf (California Department of Water Resources 2003; Montgomery Watson and Water Education Foundation 2000; Purkey et al. 1998; Purkey and Mansfield 2002; U.S. Army Corps of Engineers 2002; Kennedy/Jenks 2008).This estimate is based on the assumption of increased available groundwater through reoperation of existing groundwater systems. More aggressive estimates from studies indicate the potential to increase average annual water deliveries by two maf. For the purpose of comparison, the lower and higher estimates amount to 1.2 and 5.0 percent of the average annual water supply in California, and 3.0 and 12.1 percent of the average annual groundwater supply. The increase in groundwater supply may result in increased competition for the groundwater resources, which could potentially impact the agricultural economy of the state. As noted earlier, the attempt to build a solid inventory of data on conjunctive management projects on a regional and statewide basis did not meet with considerable success. As a result, estimates of range of supply increase from potential conjunctive management projects could not be further refined in Update 2013. Better estimates can only be developed once the inventory of conjunctive management projects is properly refined and updated in future California Water Plan updates.

The more aggressive estimates are based on assumptions that require major reoperation of existing surface water storage and groundwater storage to achieve the benefits and do not fully consider the conveyance capacity constraints for exports through the Delta and other conveyance facilities (California Department of Water Resources 2003; Montgomery Watson and Water Education Foundation 2000; Purkey et al. 1998; Purkey and Mansfield 2002; U.S. Army Corps of Engineers 2002; Kennedy/Jenks 2008). This estimate could be considerably lower if either major reoperation of existing surface water storage and groundwater storage is not feasible, or existing conveyance capacity constraints for exports through the Delta and other conveyance facilities are taken into consideration.

Potential Costs

Costs for implementation of conjunctive management and groundwater storage may include a wide range of facilities and depend on the site-specific nature of the program. Accordingly, the cost for a unit increase in water supply or delivery is highly variable.

Some projects require relatively minor changes in operations or upgrades of existing infrastructure, such as increased sizing of pumps in existing wells or increased releases of water from existing conveyance canals. Other projects may require extensive new facilities such as canal turnout structures, new pipelines and pumps, injection or extraction wells, or construction of new recharge basins. The highly variable nature of implementation costs requires that the feasibility of new conjunctive management projects or programs be evaluated carefully on a case-by-case basis. Generalizations of implementation costs without site-specific information on issues, such as available water supply and access to conveyance and groundwater storage, are rarely accurate.

The wide range of costs results from many factors including project complexity, regional differences in construction and land costs, availability and quality of recharge supply, availability of infrastructure to capture, convey, recharge, and extract water, intended use of water, and treatment requirements. Additional issues that may also need to be addressed are who has ownership of the water and who compensates for disputes among neighbors and impacts to or from third parties. In general, urban uses can support higher project costs than agricultural uses.

Major Implementation Issues

Uncertainty in Surface Water Availability from State and Federal Water Projects

For many regions in the state, water supply from SWP and CVP is a potential source for groundwater recharge. However, its availability has become increasingly uncertain because of the deterioration of environmental conditions in the Delta. Recent legal decisions (Wanger 2007a; 2007b; 2008a; 2008b; 2010; 2011a; 2011b) and biological opinions (U.S. Fish and Wildlife Service 2008, 2011; National Marine Fisheries Service 2009, 2011) have narrowed the time window of Delta pump operations. As a result, less water can be exported for delivery to south of the Delta. Information about SWP water supply reliability (updated every two years) can be obtained at http://baydeltaoffice.water.ca.gov/swpreliability/. The increased uncertainty in surface water availability from SWP and CVP could be a critical limiting factor to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

Uncertainty in Evaluating Impacts of Groundwater Pumping on Surface Water Flows and Aquatic Ecosystems

Groundwater and surface water are usually connected hydraulically. Conjunctive water management can change existing surface water and groundwater interaction significantly. There are some regional groundwater flow models available for the Central Valley, and they can be used to evaluate the surface water and groundwater flow interaction. However, the accuracy of analysis, model resolution, and the size of the modeling area often limit their application for evaluation of local and regional as well as statewide conjunctive water management opportunities. Impacts to aquatic ecosystems often require the modeling of water temperatures and solute transport, land subsidence analysis, and identification of environmental flow targets. These modeling tools are not well developed or integrated for conjunctive management planning as discussed in the *Lack of Data and Tools* section below.

Effects of Land Use Changes on New or Enlarged Recharge Facilities and Recharge Area Protection

A natural recharge area may be reduced or eliminated because of a new development or contamination from a development. The protection and the improvement of natural recharge areas are important in maintaining and improving groundwater storage. In California, floodplains and wetlands that provide natural recharge areas have been urbanized at a steady pace, although the pace has somewhat stabilized since the economic slowdown beginning in 2008. Proximity of some developments to existing groundwater recharge facilities precludes expansion of recharge area.

With the cost of land increasing, better land use planning is required to preserve natural recharge areas by limiting the encroaching development, for example, by purchasing the land or by zoning the land for recharge-friendly uses. However, protecting an important natural recharge area sometimes may not be a high priority for the county or local land use authorities, particularly if the groundwater basin being pumped is in another jurisdiction. Although federal, State, county, and local requirements may mitigate impacts of increased runoff resulting from new developments, these requirements may need to be further strengthened by additional provisions that may also include local land use ordinances. While recognizing that there is variability in hydrology, and local conditions and needs, these provisions or ordinances should generally be geared toward ensuring that new developments incorporate detention ponds so that the increased runoff and lost natural recharge can be offset by the planned detention ponds, accomplished in such a way that groundwater quality is not compromised. However, instead of this approach and if workable, an alternative basin-wide or watershed-scale approach may also be taken to mitigate the effects of new developments in a more cost-effective way at the basin or watershed level. The proposed detention ponds can provide flood protection and also help maintain natural recharge. Managed recharge facilities may be used to inject the increased runoff to the underlying groundwater basin. One significant initial step in this direction was the passage of AB 359 in 2011, which requires local groundwater agencies to include a map in groundwater management plans that identifies groundwater recharge areas in their basins and to provide these recharge area maps to local planning agencies. The issues related to land use and recharge area protection are further discussed in Chapter 20, "Urban Stormwater Runoff Management" and Chapter 25, "Recharge Area Protection" in this volume.

Recently, Calaveras County has added a new dimension to the on-going discussion of land and water use nexus by introducing the concept of water element in its general plan. The county defines a water element as "a self-contained document that identifies and articulates goals, policies, and objectives for the multiple uses of water. It can address all or some of these uses, such as water supply, wastewater, water quality, stormwater management, flood management, watershed management, protection of habitat, and erosion control. It does not dictate land use planning; it informs land use planning." The goal as articulated by the county is "by integrating these various aspects in a Water Element there will be greater opportunity for improving the linkage between land use decisions and water planning; standardizing services; increasing public awareness; and…." (Montgomery Watson Harza 2009).

Inconsistency and Uncertainty in Regulatory Status with Respect to Recharge and Surface Commingling of Different Quality Water

Groundwater recharge involves using water from various sources to recharge a groundwater basin. The quality of water used for recharge is usually different from the water in the receiving groundwater basin. Uncertainty in regulatory status with regard to the quality of recharging and receiving waters increases the uncertainty in the planning effort of conjunctive management and may increase cost or even make a conjunctive water management project infeasible during implementation.

Lack of Data and Tools

Data and tools are very important in developing a reliable and advanced conjunctive water management strategy. Data are needed to understand the groundwater resource, to monitor and measure the progress of water management strategies, and to calibrate and validate computer modeling tools. However, data are often lacking. Tools are also not readily available for use and may need to be developed. Existing tools may also need to be refined and improved, as discussed later in this section.

Data are needed to evaluate conditions and trends laterally and vertically in a geographic area and over time. The CASGEM Program has been implemented to monitor groundwater elevations and the Groundwater Ambient Monitoring and Assessment Program (GAMA) has been implemented to monitor groundwater quality. Besides these two programs, there are few comprehensive basin-wide networks to monitor groundwater levels, water quality, land subsidence, and interaction of groundwater with surface water and the environment. There is no centralized database or integrated information system providing access to various groundwater monitoring networks operated by various State and local agencies. DWR released the first such product called the Integrated Water Resources Information System (IWRIS) in May 2008 to the public, but IWRIS does not include or provide access to much of the available water quality data.

To understand the groundwater resources on a statewide basis, data from throughout the state are needed. Although data in remote areas may not be available because remote areas are not usually monitored by local authorities, these data are important for understanding the statewide groundwater system. A statewide groundwater modeling tool can help identify cost-effective and necessary locations and frequency of groundwater monitoring. An integrated statewide data and information management system such as IWRIS can also help visually identify the spatial data gaps in the state. Because of the lack of resources, incentives, or conflicts of interest, individuals or local agencies are usually not able to fill the spatial data gaps outside their management areas. State agencies could help fill the data gaps by providing the necessary resources to local agencies. Better cooperation and coordination are also needed among the agencies to best use available resources to develop a statewide groundwater monitoring program by minimizing data gaps and overlaps. The greatest obstacle to the continuation and success of any data program is the lack of dedicated funding for program execution by State agencies and participating local agencies. Success of these important data monitoring programs can only be ensured through long-term commitment and funding at the State and local levels.

One important aspect in data collection effort that is often overlooked is its coordination with the development of computer models. Computer models help identify potentially critical data collection locations (stations) and the desired frequency of collection, leading to improved monitoring of groundwater systems and performance measurement of management strategies. The coordination between data collection and model development would also help improve model calibration and reduce cost of data collection by minimizing data gaps and overlaps. While a model may have its own set of limitations, an easy-to-use computer aided conjunctive management tool is needed for assessing the management strategies and quantifying the values of the strategies. The tool should allow managers to define and prioritize objectives and specify constraints in an easy-to-use interface. The tool should also be able to perform integrated surface water and groundwater modeling, land subsidence analysis, and economic evaluation.

Computer models have been developed to assist water resources planning and management and there is continued development of these models. CalSim II (Close et al. 2003), jointly developed by DWR and the U.S. Bureau of Reclamation, is a recognized water resources planning model for SWP and CVP operations running in monthly time step. Groundwater models are also under development for selected hydrologic regions. One of the groundwater models covering the Central Valley is the California Central Valley Groundwater-Surface Water Model (C2VSim). It simulates three groundwater layers and model calibration was recently completed (Brush 2013). The model was officially released in June 2013. A similar model, called the Central Valley Hydrologic Model (CVHM), was developed and released by the U.S. Geological Survey (Faunt 2009). However, before either C2VSim or CVHM can be used for local groundwater management, its modeling resolution needs to be improved. Effort to improve the spatial resolution of C2VSim has commenced recently. Availability of a model with finer spatial resolution is extremely important because while the State’s goal is to encourage conjunctive water management statewide, the effects of bad management are felt locally by citizens dependent on groundwater. While many areas in the state rely on surface water or has access to surface water, in some areas more than 70%

of the agriculture is groundwater dependent, as documented and available online in *Water Plan Update 2013 Volume 4, Reference Guide – California's Groundwater Update 2013*.

A recently published report documents a planning level analysis performed to assess and quantify general viability of conjunctive water management projects in the Sacramento Valley. The analysis was conducted by sequentially using a simplified surface water model in conjunction with CalSim-II to simulate CVP/SWP operations and SacFEM based on MicroFEM (Hemker 2013) to assess impacts of proposed projects on groundwater levels and streamflows. The analyses provided a general estimate of potential benefits resulting from the proposed projects. However, the report notes that the analysis will need to be refined for specific project implementation by clearly incorporating infrastructure and operational protocols and analyzing response of the simulated surface and groundwater water system (CH2MHill and MBK Engineers 2010)

A recent effort to integrate C2VSim with an updated version of CalSim II called CalSim III (California Department of Water Resources 2013d), may offer a broader water resources modeling system and provide an opportunity for developing an integrated groundwater and surface water modeling system for the entire state (Young 2007; Joyce 2007). To be a good conjunctive water management tool, more modeling capabilities need to be added and integrated in the modeling system. Modeling capabilities that need to be added are:

- Water temperature modeling.
- Daily time step modeling of CalSim instead of monthly time step.
- A user-friendly interface.
- Capability to specify management objectives and constraints.
- Groundwater modeling beyond the Central Valley to cover possible salt water intrusion and address groundwater issues relevant to other hydrologic regions.
- Environmental and economic analysis.

Other available models or modeling system also lack these capabilities. As conjunctive management is sensitive to the temperature shifts as well as the type, amounts, and patterns of precipitation that affect the hydrologic system, model refinements must also allow incorporation of variable climatological scenarios to provide confidence in its projections for conjunctive management. Although there has been recent increased effort to do that, these refinements need to be further improved to ensure that climate change projections are properly reflected in model simulations.

The lack of data and tools to evaluate the groundwater and surface water interaction has hindered conjunctive water management and water transfer practices because of the failure to quantify compensations to injured parties. The inability to identify the impact of groundwater pumping on surface water and aquatic ecosystems fully, adds to the risk of effective conjunctive water management planning. To overcome this hurdle, sufficient funding must be committed to State agencies and where applicable, local and regional agencies to ensure that the required data and tools are incrementally developed and refined.

Public Access to Well Completion Reports

Although there are many wells in the state, the well completion reports are not accessible to the public because of confidentiality requirements (California Water Code Section 13752). If the relevant California

Water Code sections are changed to remove confidentiality of well completion reports while upholding the coordinated national program to protect the nation's critical infrastructure, the geologic and groundwater related information in the existing well completion reports would be accessible to the public, which in the long-run could save money and time for collecting aquifer and groundwater information. To that end, SB 263 (Well-Reports-Public Availability) was introduced in 2011. It passed through the Senate and Assembly, but the governor vetoed it citing amendments to the bill that unduly restricted the use of the well completion reports and imposed severe criminal penalties for disclosure. A modified version of the bill, SB 1146, was introduced in 2012 to make well logs public information. The bill would have required DWR to make the well reports public subject to specified limitations. It was defeated in the Senate floor, but another version of the bill is expected to be introduced in the future.

Currently, DWR's Regional Offices fill requests for Well Completion Reports as provided for in the California Water Code. And, whenever staff members are not sure how to handle certain requests, they seek advice and guidance from DWR's Office of the Chief Counsel. Each year, thousands of Well Completion Reports are made available to governmental agencies, persons doing groundwater clean-up studies, well owners, and other people as provided by the California Water Code.

It is unlikely that a change in the law to make Well Completion Reports public would save the State money and time in the short-run. Indeed it would probably cost DWR time and money for several years. DWR may save time and money if all Well Completion Reports were scanned and available on the Web and if an online filing system were developed for well drillers to submit new Well Completion Reports in the future. However, both of these systems would require significant amounts of money and time to develop.

Thus changing Section 13752 must be done based on sound and compelling arguments. The following capture some of the important considerations in that regard:

- Sufficient funds should be provided to cover the cost to implement changes in Section 13752.
- Language must be included in the law for DWR to recover actual costs of providing Well Completion Reports to the public.
- The law should ensure continuation of collecting the same level of information as is collected currently on the Well Completion Reports, i.e., the usefulness and value of the Well Completion Reports should not be diminished or sacrificed.
- The law should ensure that the quantity and quality of the information provided by the well drillers does not diminish.

Infrastructure and Operational Constraints

Physical capacities of existing storage and conveyance facilities are often not large enough to capture surface water when it is available in wet years. Conveyance capacity for surplus imported water supplies is most available during the wetter and cooler months when water demand is low. However, this wetter period also coincides with reduced ability to accomplish in-lieu recharge (due to lower water demands) and with increased spreading of local runoff, which may limit the ability to recharge other sources of water. During the very wet year of 2004-05, active recharge throughout the Metropolitan Water District service area used only 60 percent of the total recharge facility capacity available throughout the course of the year (Metropolitan Water District of Southern California 2007).

Operational constraints may also limit the ability to use the full physical capacity of facilities. For example, permitted export capacity and efforts to protect fisheries and water quality in the Delta often limit the ability to move water to groundwater banks south of the Delta. Facilities that are operated for both temporary storage of floodwater and groundwater recharge require more frequent maintenance to clean out excessive sediment often present in floodwater.

The need to improve coordination of infrastructure and operations for flood control and recharge of storm flows for conjunctive management cannot be overstated. In Southern California as well as in other areas of California, the considerable opportunity to enhance groundwater recharge by local runoff remains unrealized because of a lack of streamlined and effective coordination.

Another issue that cannot be overstated is the urgent and crucial need for increased capacities for both surface water storage systems and Delta conveyance facilities. As a result of more stringent regulatory requirements coupled with potentially detrimental effects of climate change, availability of surface water is anticipated to follow more extreme cycles of extended dry spells intervened by short, high intensity wet spells. In the new reality, absence of additional surface water storage and Delta conveyance would be critical limiting factors to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

Surface Water and Groundwater Management

In California, as in other states, water management practices and the water rights system traditionally have treated surface water and groundwater as two unconnected resources. However, as explained previously, there is often a high degree of hydraulic connection between the two. Under predevelopment conditions, many streams receive dry-weather flow or baseflow from groundwater, and streams provide wet weather recharge to groundwater. Water quality and the environment can also be influenced by the interaction between surface water and groundwater. Incomplete understanding of these connections can lead to unintended consequences. The planning of conjunctive management should consider and evaluate potential impacts resulting from groundwater and stream interaction, including those on the environment. For example, studies by the University of California, Davis indicate that long-term groundwater pumping in Sacramento County has reduced or eliminated dry season baseflow in sections of the Cosumnes River with potential impacts on riparian habitat and anadromous fish (Fleckenstein et al. 2004).

The authority for managing different aspects of groundwater and surface water resources in California is separated among federal, tribal, State, and local agencies. Several examples highlight this issue:

1. State Water Resources Control Board regulates surface water rights dating from 1914, but not rights prior to 1914.
2. Regional Water Quality Control Boards regulate waste discharges that might impact groundwater quality, but not the rights to use groundwater.
3. County groundwater ordinances and local agency groundwater management plans often apply only to a portion of the groundwater basin, and counties or local agencies with jurisdictions that overlie the same groundwater basin do not necessarily have consistent management objectives in their groundwater ordinances or management plans.
4. Except in adjudicated basins and in some areas with adopted groundwater management plans, individuals have few restrictions on how much groundwater they can use, provided the water has beneficial uses. Because of the connection between surface water and groundwater,

unmanaged groundwater use will eventually affect other water users and may have significant impacts on the environment and economy. Incomplete understanding of these connections can lead to unintended consequences if projects are designed and built to increase groundwater extraction without adequate safeguards to forestall the potential adverse impacts.

Because most groundwater systems are slow responding systems, any damage to the system may require long periods to recover and any effects on third parties may take a considerable time to reach detectable levels. Planning, monitoring, evaluating, and maintaining a management structure that is able to react to unplanned consequences are keys for successful groundwater management. Sustainable conjunctive water management is an important strategy to deal with the existing and future water supply challenges. Management of the entire groundwater basin or hydrologic region is essential for effective conjunctive water management. Conjunctive management will be more effective and efficient if multiple hydrologic regions work together so that the weaknesses and strengths of regions can be coordinated and used for mutual benefit. However, the existing legal and regulatory framework on groundwater use will make it very difficult to plan any large-scale conjunctive water management strategies because groundwater management is a local responsibility (Sax 2002). Under this legal framework, the conjunctive management strategy that can be pursued with minimal effort is limited to groundwater recharge at the local level with local surface water. The State’s role in conjunctive management is limited to providing funding to help willing local agencies plan and implement conjunctive management.

Most groundwater management ordinances restrict out-of-county groundwater uses. Some groundwater management plans specify trigger levels for groundwater levels in the basin management objectives (BMOs) to prevent overdraft or water quality problems. However, in many cases there are no mechanisms to address the non-compliance with the BMOs. The current groundwater ordinances, AB 3030 and SB 1938 groundwater management plans and local BMO activities, which were intended for localized groundwater management, appear not to be well suited for implementing regional groundwater management. Recent development in water planning through the collaborative IRWM framework may, however, pave a way to increase cooperation and collaboration among local and regional water entities to design and implement regional conjunctive management programs and projects that will preserve and promote the interests of all stakeholders. Legal and scientific ways of settling the issue of ownership/extraction rights in a multi-jurisdictional/multi-land owner groundwater basin would be a crucial hurdle to overcome to make regional conjunctive management projects viable and successful.

Water Quality

Groundwater quality can be degraded by naturally occurring or human-introduced chemical constituents, low quality recharge water, or chemical reactions caused by mixing water of differing qualities. Protecting human health, the environment, and groundwater quality are all concerns for programs that recharge urban runoff or recycled water into groundwater. The intended end use of the water can also influence the implementation of conjunctive management projects. For example, agriculture can generally use water of lower quality than is needed for urban use, but certain crops can be sensitive to some constituents such as boron.

New and changing understanding of water quality constituents, including emerging contaminants and their risks to human and ecological health, result in changing water quality standards. While this may lead to more healthful water supplies, it also adds uncertainty to planning and implementing conjunctive management projects. A water source may, at the time it is used for recharge, meet all drinking water quality standards. Over time, however, constituent detection capabilities improve and new or changed water quality standards become applicable. As a result, contaminants that were not previously identified or detected may become future water quality problems creating potential liability. In some cases, conjunctive management activities may need to be coordinated with groundwater cleanup activities to achieve multiple benefits to both water supply and groundwater quality.

When water is diverted from streams providing inflows to the Delta, there should be an evaluation of the possible impacts on Delta salinity. Increasing surface storage releases is an option to reduce the impacts on Delta salinity. Various alternative options to address salinity and other critical issues in the Delta are being analyzed and evaluated under the Bay Delta Conservation Plan (California Natural Resources Agency 2013). The preliminary drafts of the plan have been released in multiple stages during March and April 2013.

Environmental Concerns

Environmental concerns related to conjunctive management projects include potential impacts on habitat, water quality, and wildlife caused by shifting or increasing patterns of groundwater and surface water use. For example, floodwaters are typically considered water that is “available” for recharge. However, flood flows serve an important function in the ecosystem. Removing or reducing peak flood flows may impact the ecosystem negatively. A key challenge is to balance the instream flow and other environmental needs with the water supply aspects of conjunctive management projects. There may also be environmental impacts from construction and operation of groundwater recharge basins and new conveyance facilities. Conversely, groundwater recharge facilities in some locations may provide important habitat for a variety of wildlife.

Climate Change

Significant changes to California's hydrologic cycles have been measured by DWR and others in recent years. In the past 100 years, changes in snowpack, runoff timing, and sea level rise have all affected water manager's ability to capture and deliver water when needed. The anticipated future effects of climate change in California include more extreme flood events in the winter, an overall decrease in Sierra Nevada snowpack, more frequent droughts, and a continued sea level rise (California Department of Water Resources 2008). Managing California's water supply under 21st century climate conditions will involve adapting and reacting to changes while finding ways to minimize associated energy use. Higher temperatures and changes in runoff patterns resulting from climate change are expected to make droughts occur more frequently and continue for longer periods. As a result, many areas will rely more on groundwater due to reduced surface water supplies. In order to meet this challenge posed by climate change, surface and groundwater resources should be managed conjunctively with the long-term goal of sustaining both these resources.

Adaptation

The planning process for conjunctive management should consider the potential climate change impacts described above and include projects to increase regional resilience. Projects that provide climate adaptation benefits may include surface water storage and groundwater recharge facilities to capture flood flows, injection wells to prevent salt water intrusion in coastal areas and protect water quality, and conveyance facilities to move water from regions with excess supply to drought-affected areas.

Conjunctive management plans that integrate floodplain management, groundwater banking, and surface storage could help facilitate system reoperation and provide a framework for the development of local projects with widespread benefits for larger regions.

Additional information on the potential for conjunctive management as a climate change adaptation strategy can be found in *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water* (California Department of Water Resources 2008).

Mitigation

Under conditions of climate change, mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Conjunctive management can be used as a mitigation tool. Groundwater recharge prevents water tables from dropping and then being pumped from lower depths with high energy costs. Managing water in a way that keeps it available within a region during peak use periods prevents the use of energy-intensive alternative water sources. Conjunctive management can also be a source of greenhouse gas emissions from energy consumed by injection wells, conveyance systems, or the building and maintenance of conjunctive management facilities. Therefore, costs and benefits must be carefully weighed.

Funding

There is generally limited funding to develop the infrastructure and monitoring capability for conjunctive management projects. Funding is available as incentives to local agencies to cooperate in the development and implementation of IRWM and groundwater management plans, to study and construct conjunctive management projects, and to track (both statewide and regional) changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, surface water flow, surface water quality, and the interaction of surface water and groundwater.

Recently, Amant (2013) in an insightful document further illuminates critical issues that could potentially hinder widespread implementation of conjunctive water management in the Sacramento Valley.

Recommendations

1. **Promote public education about California's groundwater.**
   By July 1, 2016, DWR and SWRCB will work with other State, tribal, local, and regional agencies and organizations to develop a groundwater education program and materials for use in the schools and public outreach. Key educational concepts should include
   A. Groundwater supply variability.
   B. Interconnection of surface water and groundwater.
   C. Groundwater recharge benefits and challenges.
   D. Importance of protecting groundwater quality and recharge areas.
   E. Seasonal versus long-term changes in groundwater quantity.
   F. Importance of developing a groundwater budget.
   G. Potential impact of climate change on groundwater resources.

2. Improve collaboration and coordination among State, federal, tribal, local, and regional agencies and organizations to ensure data integration, coordinate program implementation, and minimize duplication of efforts.

By January 1, 2017, and on an ongoing basis, DWR and the SWRCB will coordinate with State, federal, tribal, local, and regional agencies and organizations to conduct the following activities.

A. Provide State incentives to local water management agencies to coordinate with Tribes and other agencies involved in activities that may affect long-term sustainability of water supply and water quality.

B. Outline and implement process to improve coordination and cooperation among State, federal, tribal, and local agencies to improve the process for timely regulatory approval, alignment of rules or guidelines, and environmental permitting for the development, implementation, and operation of conjunctive management, recharge, and water banking facilities.

C. Expedite environmental permitting for implementation of conjunctive management, recharge, and water banking facilities when facility operations increase ecosystem services, and includes predefined benefits/mitigation for wildlife and wildlife habitat.

D. Establish a process led by the SWRCB to identify measures whereby agencies proposing to use peak surface water flow for groundwater recharge are not subject to potential protest of their existing water right, in order to stipulate groundwater recharge as a reasonable beneficial use of their surface water right.

3. Increase availability and sharing of groundwater information.

DWR will coordinate with State, federal, tribal, local, and regional agencies and organizations to conduct the following activities.

A. By January 1, 2016, Governor's Office of Planning and Research (OPR) will develop a coordination plan to disseminate groundwater information.

B. By January 1, 2016, the State of California will consider changes to Section 13752 of the California Water Code to improve public access to Well Completion Reports, while addressing key infrastructure security and private ownership concerns. The relevant State agencies will be appropriately funded to implement the directives of the legislature in the changed law.

C. By January 1, 2018, State agencies will work collaboratively with water agencies, local permitting agencies, and driller organizations to i) develop an on-line Well Completion Report submittal system, ii) digitize and make publically available existing Well Completion Reports to allow improved analysis of groundwater data, and iii) build upon efforts begun in 2012 to update well drilling, construction, and abandonment standards.

D. By December 31, 2018, DWR will work with SWRCB to implement a web-based Water Planning and Information Exchange (Water PIE) system that will provide on-line access to groundwater supply and demand information, groundwater level and quality data, groundwater recharge and conjunctive management activities, groundwater management planning, land subsidence information, and groundwater basin studies.

4. Strengthen and expand the CASGEM Program for its long-term sustainability.

A. By January 31, 2015, and renewable in each five-year cycle ending in 8 and 3, the State of California will commit long-term, dedicated funding to the CASGEM Program to implement monitoring, assessment, and maintenance of baseline groundwater levels data, and expand the program to include the fractured rock hydrogeology in areas deemed important.

B. By January 31, 2015, and renewable in each five-year cycle ending in 8 and 3, the State will continue funding for local groundwater monitoring and management activities, and feasibility studies that increase the coordinated use of groundwater and surface water by giving priority to projects that include filling regional and Statewide data gaps and conjunctive management conducted in accordance with an IRWM plan. Thus encourage or require and provide incentives to local water management agencies to implement groundwater monitoring programs to provide additional data and information needed to adequately characterize a groundwater basin, subbasin, aquifer or aquifers under the jurisdiction of the agency or adopted groundwater management plan. Box 9-9 lists the items that a data collection program should include.

C. By December 31, 2018, the State will expand and fund CASGEM by including and implementing above recommendations as integral components of the Program, and thus use CASGEM as the vehicle to update and maintain groundwater information in the future.

PLACEHOLDER Box 9-9 Components of A Data Collection Program

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

5. Under the CASGEM Program, improve understanding of California groundwater basins by conducting groundwater basin assessments of CASGEM high priority basins in conjunction with the California Water Plan (CWP) five-year production cycle.

By December 31, 2018, DWR will coordinate with State, federal, tribal, local, and regional agencies to utilize the CASGEM Basin Prioritization information to conduct the following groundwater basin assessment activities.

A. Develop the initial and reoccurring schedule and scope for groundwater basin assessments that will allow data and information sharing under the CWP five-year production cycle.

B. Compile and evaluate new and existing groundwater supply and demand information, groundwater level and quality data, groundwater recharge and conjunctive management activities, surface water/groundwater interaction, groundwater management planning, land subsidence information, and existing groundwater basin studies, in accordance with the scope identified in (a).

C. Develop detailed groundwater basin assessment reports by Hydrologic Region and groundwater basin. The reports will characterize sustainability of groundwater resources in terms of historical and existing trends and future scenario projections, and will identify recommended incentives to establish basin-wide groundwater budgets and adaptive management practices which will promote sustainable groundwater quantity, quality, and the maintenance of groundwater ecosystem services. Box 9-10 lists the inflow and outflow components that make up a groundwater budget.

D. Develop a summary report to California Legislature depicting the State of California's Groundwater which will highlight key findings and recommendations associated with detailed groundwater basin assessments by Hydrologic Region.

PLACEHOLDER Box 9-10 Components of A Groundwater Budget

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

6. **Conduct an assessment of all SB 1938 groundwater management plans and develop guidelines to promote best practices in groundwater management.**

   In coordination with State, federal, tribal, local, and regional agencies, DWR will conduct the following activities.

   A. By January 1, 2015, the Legislature will amend the appropriate code(s) to authorize DWR to evaluate and assess groundwater management and planning, and to develop groundwater management and implementation guidelines.
   B. By January 1, 2016, DWR will conduct outreach to local and regional agencies to supplement and verify Groundwater Management Plans (GWMP) inventory and information initiated by DWR as part of Update 2013.
   C. By January 1, 2017, DWR will work with regional and local agencies to assess their GWMP implementation and practices, in accordance with existing California Water Code requirements to i) identify technical, legal, institutional, physical, and fiscal constraints associated with existing groundwater management programs, ii) identify opportunities associated with groundwater management and planning activities, and iii) gain an understanding of how agencies are implementing actions to use and protect groundwater.
   D. By January 1, 2018, DWR will work with regional and local agencies to develop groundwater management and planning and program implementation guidelines. The guidelines will provide a clear roadmap for GWMP development and implementation by identifying and clarifying components, processes, and standards and by establishing provisions for periodic review, report, update, and amendment as necessary to facilitate effective and sustainable groundwater management. The guidelines will also emphasize groundwater management in coordination with or as part of an IRWM plan.
   E. By December 31, 2018, DWR will convene a GWMP Advisory Committee and begin coordination with regional and local agencies and tribal communities that have not developed basin-wide GWMPs, to develop such plans with assistance and guidance from the GWMP Advisory Committee. The GWMP Advisory Committee will help guide the development, educational outreach, and implementation of the GWMPs. Advanced tools development should be pursued as part of this activity to help quantify benefits and assess robustness of alternative management strategies.

7. **Develop analytical tools to assess conjunctive management and groundwater management strategies.**

   By December 31, 2018, DWR and the SWRCB, in collaboration with State, federal, tribal, local, and regional agencies will conduct the following activities.

   A. Develop a conjunctive management tool that will help identify conjunctive management opportunities (projects) and evaluate implementation constraints associated with the i) availability of water for recharge, ii) available means to convey water from source to destination, iii) water quality issues, iv) environmental issues, v) jurisdictional issues, vi) costs and benefits, and vii) the potential interference between a proposed project and existing projects.

B. The State will encourage or require local and regional agencies to develop or adopt analytical tools to support integrated groundwater/surface water modeling and scenario analysis for assessing alternative groundwater management strategies as part of their IRWM planning activities.

8. **Increase Statewide groundwater recharge and storage by two maaf (current average annual Statewide groundwater use is about 16 maf).**
The following activities will occur through coordination among State, federal, tribal, local, and regional agencies.
A. By January 1, 2016, the Legislature will revise the Water Code to i) include disincentives to overdraft groundwater basins and ii) include incentives for increasing recharge.
B. By January 1, 2017, DWR will compile, assess, and provide status update on Statewide aquifer recharge area delineation and mapping required by AB 359 and to identify priority recharge areas.
C. By January 1, 2017, State agencies will work with federal, Tribal, local, and regional agencies to i) develop guidelines clarifying interagency alignment and improved interagency coordination to facilitate local groundwater recharge and storage projects, ii) develop guidelines for coordinating and aligning land use planning with groundwater recharge area protection, and iii) catalogue best science and technologies applied to groundwater recharge and storage.
D. By January 1, 2018, DWR and SWRCB will compile available data, identify missing data needed to evaluate natural groundwater recharge, discharge, related ecosystems, and groundwater recharge and storage projects, and develop a plan to fill identified data gaps to support evaluation of groundwater recharge and storage.
E. By January 1, 2018, and on an ongoing basis, the State will encourage local and regional agencies - when technically, legally, and environmentally feasible – to manage the use of available aquifer space for managed recharge and develop multi-benefit projects that generate source water for groundwater storage by capturing water not used by other water users or the environment.
F. By December 31, 2018, the State will encourage and fund local and regional agencies, and tribal communities to i) identify and evaluate local and regional opportunities to reduce runoff and increase recharge on residential, school, park, and other unpaved areas, ii) coordinate groundwater recharge and multi-benefit flood control projects to enhance recharge using storm flows, and iii) conduct pilot studies (one regional and one inter-regional) to identify additional opportunities and needs for advancing recharge opportunities.

9. **Evaluate reoperation of the State's existing water supply and flood control systems.**
In collaboration with willing participants, DWR will complete a System Reoperation Study by 2015. The study will evaluate and document the potential options for reoperation of the State's existing water supply and flood control systems to achieve the objectives of improved water supply reliability, flood hazard reduction, and ecosystem protection and enhancement. The reoperation options will focus on integrating flood protection and water supply systems, reoperating the existing water system in conjunction with effective groundwater management, and improving existing water conveyance system.

10. DWR and the U.S. Bureau of Reclamation will:

A. Complete the North-of-the-Delta Offstream Storage, Shasta Lake Water Resources, and Upper San Joaquin River Basin Storage investigations.
B. Complete the investigation of the further enlargement of the Los Vaqueros Reservoir.
C. Complete an investigation to enlarge/raise BF Sisk Dam and San Luis Reservoir.

Investigation will be completed by the end of 2016. The above projects will also:

D. Evaluate the potential additional benefits of integrating operations of new storage with proposed Delta conveyance improvements, and recommend the critical projects that need to be implemented to expand the State's surface storage.
E. Identify the beneficiaries and cost share partners for the non-public benefits by 2015.
F. Request funding from the water bond for the public benefits portion through the California Water Commission by 2016, if a State water bond passes in 2014.

Conjunctive Management and Groundwater Storage in the Water Plan

This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions are not consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy is not discussed in the rest of Update 2013), there is no need for this section to appear.

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Personal Communications

Amant TS. Director of Strategic Analysis at the U.S. Air Force Center for Studies and Analyses (retired). Former Deputy Chief Administrative Officer for Butte County. Sept. 13, 2012 — email correspondence with Kahn A, California Department of Water Resources — part of annotated comments made on draft Conjunctive Management and Conjunctive Management resource management strategy.

Table 9-1 Potential Benefits of Conjunctive Management Implementation

Potential Benefit of Managed Groundwater Storage	Example	Major Constraints
Improved local water supply reliability	Imported surface water supplies and/or floodflows are recharged to local alluvial groundwater basin during wet years/seasons, increasing local water supply reliability.	• Availability of surface water supplies. • Limited capacity to capture and recharge high volume, short duration floodflows. • Water quality concern of the recharged water and the impact to the aquifer itself.
Improved statewide water supply reliability	Groundwater storage in the northern part of the state might be used as backup supplies to allow more aggressive operation of surface storages such as Oroville and Shasta reservoirs by permitting reduced carryover storages so that more floodflows in the wet seasons could be captured. This would increase SWP and CVP operational flexibility and could result in improved statewide water supply reliability and sustainability. The reduced carryover storage would be replaced annually by utilizing groundwater storage.	• Availability of a multi-regional/statewide conjunctive water management tool to model surface water and groundwater (including water temperature) responses accurately and to evaluate the proposed management strategy for its benefits, the impacts to third parties and the environment, project cost, etc. • Legal and water rights issues (associated impacts perhaps could be mitigated by compensation to injured parties if any, using the above tool if it were available).
Drought relief for urban water users and potential induced groundwater recharge	Groundwater substitution transfer and agricultural water transfer. Irrigators who are willing sellers stop a specific amount of surface water diversion and pump an equivalent amount of groundwater to replace surface water. As a result, more surface water becomes available downstream for purchase. Groundwater eventually recovers from increased streamflow to the groundwater system.	• A lack of a widely recognized mathematical model to quantify the impact accurately to other groundwater and surface water users and the environment. • Potential land subsidence and its quantification and evaluation.
Protection from salt water intrusion	Recharge groundwater using captured floodflows or recycled water in the vicinity of salt water interface to raise groundwater levels and prevent migration of saline water into freshwater production portions of the aquifer.	• Availability of freshwater supply. • Considerable infrastructure requirements.
Improved flood control and groundwater storage	Development of detention ponds at proposed residential subdivisions located in the groundwater recharge protection areas can offset the increased urban runoff due to the development while maintaining natural groundwater recharge.	• Possible water quality problems at detention ponds requiring effective urban storm water management. • Requiring adoption of local ordinance or legislation to support implementation.

Source: California Department of Water Resources 2013

Figure 9-1 Conjunctive Management - Project Feasibility and Development

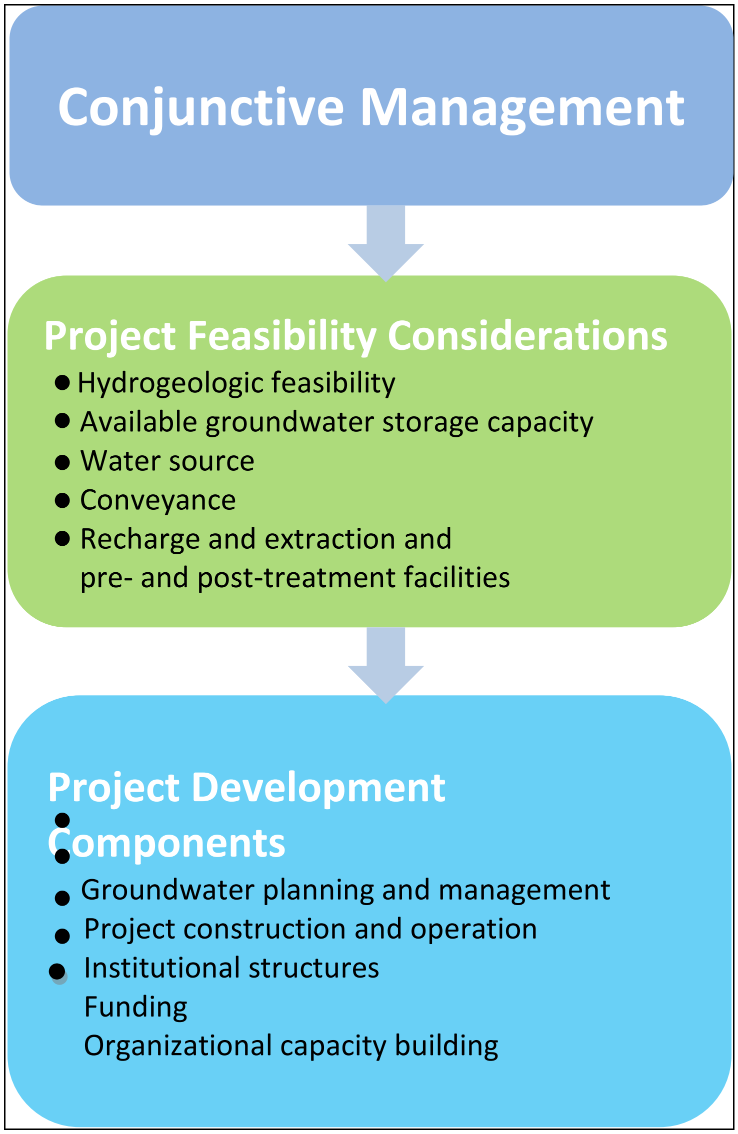
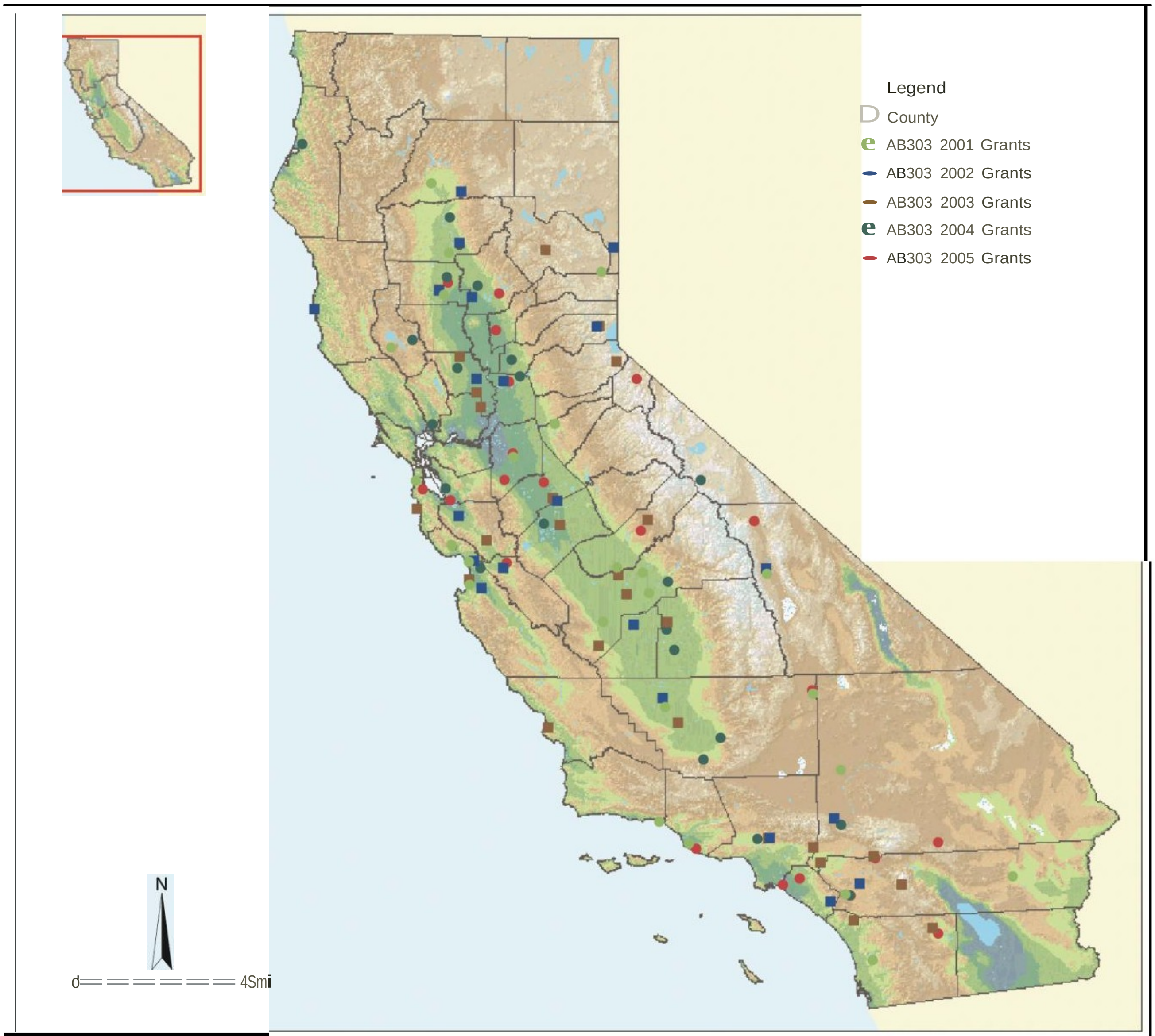


Figure 9-2 Distribution of the AB 303 Grants from 2001 to 2008



Box 9-1 Examples of Definitions of Conjunctive Water Management and Conjunctive Water Use

Example Definition 1

"Conjunctive water use primarily changes the timing in the flow of existing water sources by shifting when and where it is stored and does not result in new sources of water. Conjunctive use is often incidental as water users intuitively shift between surface water and groundwater sources to cope with changes and shortages. While conjunctive use may prove successful for an individual or group of water users to manage an immediate situation, it is also possible for conjunctive use to unintentionally harm the groundwater basin and other groundwater users who are not involved in conjunctive use but are reliant on the same groundwater basin.

An alternative to conjunctive water use is conjunctive water management. The difference between the two is more than semantics. Conjunctive water management engages the principles of conjunctive water use, where surface water and groundwater are used in combination to improve water availability and reliability. But, it also includes important components of groundwater management such as monitoring, evaluation of monitoring data to develop local management objectives, and use of monitoring data to establish and enforce local management policies. Scientific studies are needed to support conjunctive water management. They provide important data to understand the geology of aquifer systems, how and where surface water replenishes the groundwater, and flow directions and gradients of groundwater."

Dudley and Fulton 2006

Example Definition 2

"Conjunctive use and conjunctive management describe the interchangeability of ground and surface water. The difference between the terms is related to the passive nature of one versus the proactive nature of the other. Conjunctive use, with its roots in traditional water application, denotes an opportunistic or incidental interchangeability, as when an unplanned shortfall of natural ground or surface water availability causes a user to switch back and forth between sources. Typically, surface water users switch to groundwater available naturally beneath their land when surface supplies fall short of their needs. On the other hand, conjunctive management seeks to actively manage the balance of ground and surface water availability over a period of naturally occurring wetter and drier water cycles. The objective of conjunctive management is to intercede in natural groundwater recharge processes to even out the year-to-year variations in regional water availability with potential peripheral benefits of flood management, environmental water, and water quality improvement. While conjunctive use is an inherently local concept, conjunctive management with an appropriate infrastructure has the potential to span multiple regions."

Amant 2012

Example Definition 3

"Conjunctive use of groundwater and surface water in an irrigation setting is the process of using water from the two different sources for consumptive purposes. Conjunctive use can refer to the practice at the farm level of sourcing water from both a well and an irrigation delivery canal, or can refer to a strategic approach at the irrigation command level where surface water and groundwater inputs are centrally managed as an input to irrigation systems. Accordingly, conjunctive use can be characterized as being planned (where it is practiced as a direct result of management intention – generally with a top down approach) compared with spontaneous use (where it occurs at a grass roots level – generally with a bottom up approach). … Where both surface and groundwater sources are directly available to the end user, spontaneous conjunctive use generally proliferates, with individuals opportunistically able to make decisions about water sources at the farm scale.

The planned conjunctive use of groundwater and surface water has the potential to offer benefits in terms of economic and social outcomes through significantly increased water use efficiency. It supports greater food and fibre yield per unit of water use, an important consideration within the international policy arena given the critical concerns for food security that prevail in many parts of the world.

…the aim of conjunctive use and management is to maximize the benefits arising from the innate characteristics of surface and groundwater water use; characteristics that, through planned integration of both water sources, provide complementary and optimal productivity and water use efficiency outcomes."

Evans et al. 2012

Example Definition 4

"Conjunctive use of surface water and groundwater consists of harmoniously combining the use of both sources of water in order to minimize the undesirable physical, environmental and economical effects of each solution and to optimise the water demand/supply balance."

Box 9-2 Importance of Groundwater to California Water Supply

In an average year (based on 1998-2005 data), groundwater meets about 35 percent of California's agricultural, urban, and managed wetlands water uses (about 15 million acre-feet per year). In dry years, this percentage increases to 40 percent or higher statewide; and as high as 60 percent or more in specific regions (DWR, 2013a; 2013b). The importance of groundwater as a resource varies regionally. Figures A and B depict the importance of groundwater as a local supply for agricultural, urban, and managed wetlands water uses in each of California's 10 hydrologic regions. . Figure A shows the percentage of groundwater extraction in each region relative to the total groundwater extraction in the state as a whole. Figure B shows the total water use as well as the water use met by groundwater in the different regions.

With more than 80 percent of water use met by groundwater in an average year, the Central Coast Hydrologic Region is heavily reliant on groundwater to meet its local uses. The Tulare Lake Hydrologic Region meets about 50 percent of its local uses from groundwater, and South Lahontan Hydrologic Region meets an estimated 70 percent of its local uses with groundwater. The North Coast, San Francisco Bay, South Coast, Sacramento River, San Joaquin River, and North Lahontan regions meet between 15 and 35 percent of their local uses with groundwater. Percentage wise, groundwater is a relatively minor source of supply in the Colorado River Hydrologic Region (Figure B).

As shown in Figure A, of all the groundwater extracted annually in the state in an average year (based on 1998-2005 data), more than 35 percent is produced from the Tulare Lake Hydrologic Region. More than 70 percent of groundwater extraction occurs in the Central Valley (Sacramento River, San Joaquin River, and Tulare Lake regions combined). Nearly 20 percent is extracted in the highly urbanized Central Coast and South Coast regions, while about 10 percent is extracted in the remaining five hydrologic regions combined (DWR, 2013a; 2013b). With the growing limitations on available surface water exported through the Sacramento-San Joaquin Delta and the potential impacts of climate change, reliance on groundwater through conjunctive management will become increasingly more important in meeting the state's future water uses.

[The section will be revised based on updated information.]

PLACEHOLDER Figure A Percentage of Groundwater Extraction in California, Statewide and by Hydrologic Region (2002-2010 Average Annual Data)

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PLACEHOLDER Figure B Groundwater Contribution to California Water Supply by Hydrologic Region (2002-2010 Average Annual Data)

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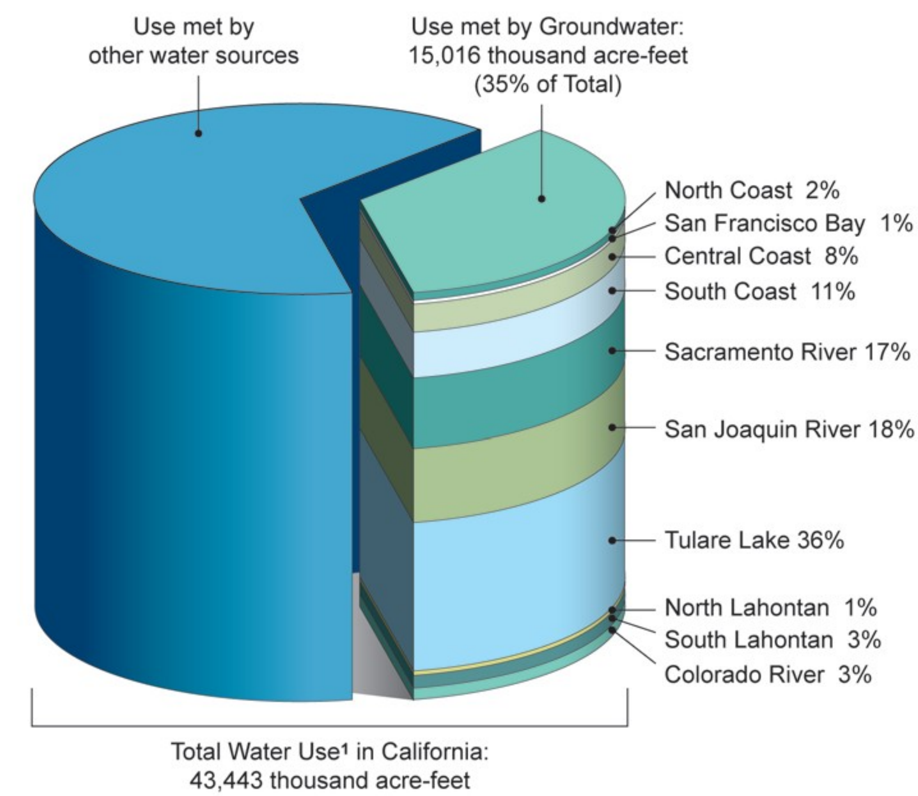
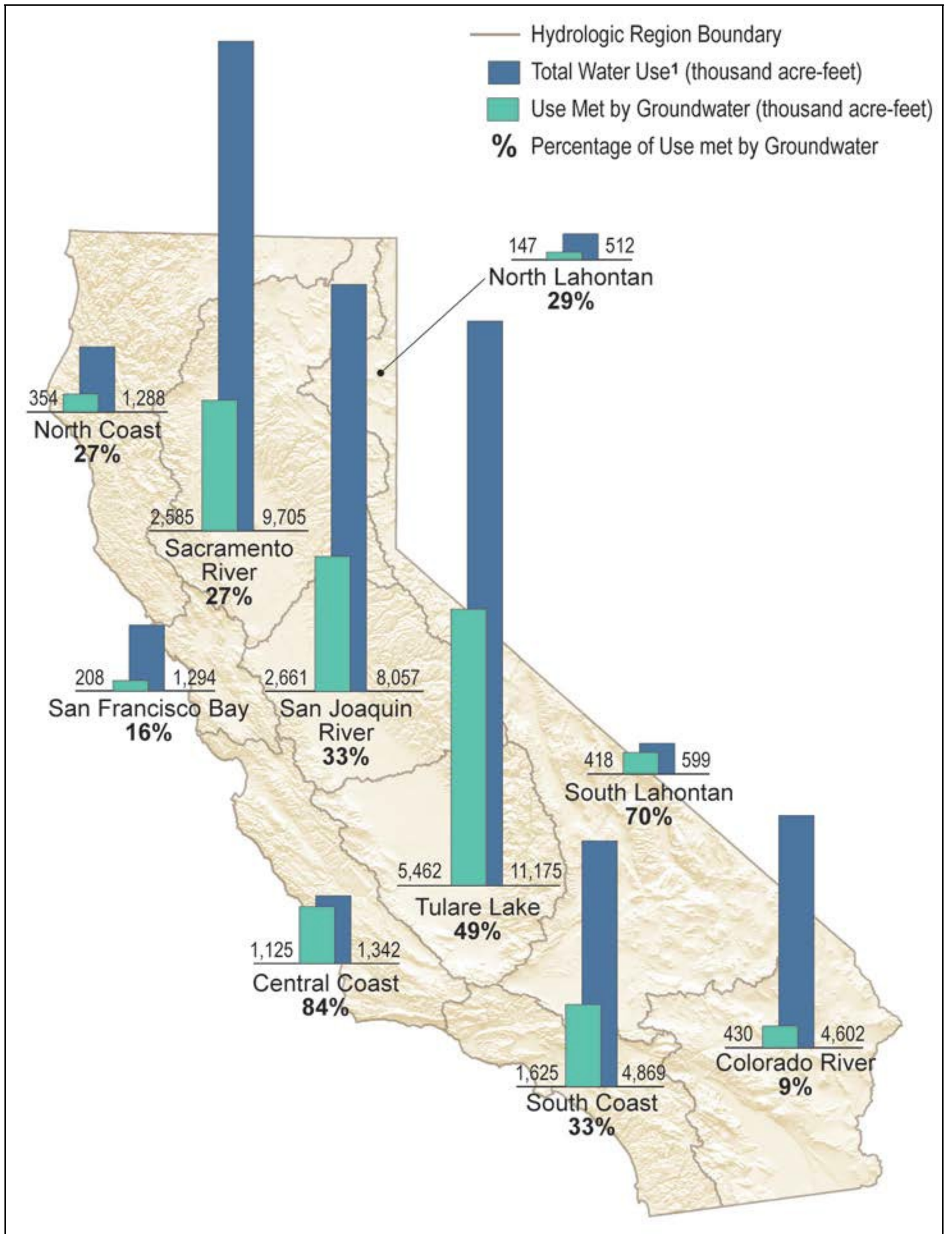
Figure A Percentage of Groundwater Extraction in California, Statewide and by Hydrologic Region (2005-2010 Average Annual Data)



1. *Total Water Use is defined as the sum of water uses for agricultural, urban, and managed wetlands.*

Figure B Groundwater Contribution to California Water Supply by Hydrologic Region (2005-2010) Average Annual Data)



1. *Total Water Use is defined as the sum of water uses for agricultural, urban, and managed wetlands.*

Box 9-3 Groundwater and Surface Water, a Single Source

Groundwater moves along flow paths of varying lengths from areas of recharge to areas of discharge. The generalized flow paths start at the water table, continue through the groundwater system, and terminate at the stream or at the pumped well. The source of water to the aquifer is infiltration through the unsaturated soil zone resulting from precipitation, irrigation applied water, managed recharge, etc. Flowlines from various aquifers to the stream can be tens to hundreds of feet in length and have corresponding travel times of days to several years or more (see Figure A below).

The interaction of streams with groundwater may take place in three different ways: streams may gain water from discharge of groundwater through the streambed (gaining stream), streams may lose water to groundwater by seepage through the streambed (losing stream), or streams may gain in some reaches (gaining reaches) and lose in some of the reaches (losing reaches). As shown in Figure B, for streams to gain water from groundwater, the stream water surface elevation must be lower than the surrounding groundwater table elevation. In contrast, as shown in Figure C and Figure D, for streams to lose water to groundwater, the stream water surface elevation must be higher than the surrounding groundwater table elevation. Losing streams can be connected to the groundwater system by a continuous saturated zone (Figure C) or can be disconnected from the groundwater system by an unsaturated zone (Figure D). A distinguishing characteristic of a stream that is disconnected from groundwater is that shallow groundwater pumping in the vicinity of the stream does not necessarily induce additional seepage of water from the stream to groundwater (Winter et al. 1998).

The direction of flow between the stream and the groundwater system may change because of storms (or flood flows moving down the stream), causing water to flow from the stream to groundwater. The direction of flow between the stream and groundwater can alter as a result of groundwater pumping near the stream. In the case of a gaining stream, pumping is likely to decrease discharge from the aquifer to the stream and in some cases, high pumping rates can even modify a gaining stream to a losing stream. In the case of a losing stream, pumping is likely to further increase seepage from the stream to the aquifer (Winter et al. 1998).

The characteristics and extent of the interactions of groundwater and surface water in an area will likely define the success of conjunctive management projects. Therefore, a better understanding of the interconnection between groundwater and surface water is instrumental for effective conjunctive management.

PLACEHOLDER Figures A,B,C,D Groundwater Surface Water, a Single Resource

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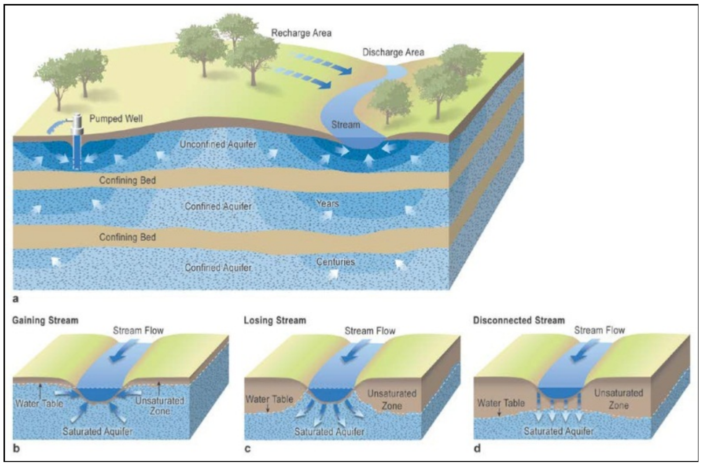
Figure A,B,C,D Groundwater Surface Water, a Single Resource



Box 9-4 Groundwater Recharge: Natural and Managed

Groundwater recharge is the mechanism by which surface water moves from the land surface, through the topsoil and subsurface, and into the aquifer, or through injection of water directly into the aquifer by wells. Groundwater recharge can be either natural or managed. Natural recharge occurs from precipitation falling on the land surface, from water stored in lakes, and from streams carrying storm runoff (Figure A). Managed recharge occurs when water is placed into constructed recharge or spreading ponds or basins, or when water is injected into the subsurface by wells. Managed recharge is also known as artificial, intentional, or induced recharge. Two widely used methods for managed groundwater recharge are recharge basins and injections wells. An additional, indirect method of managed recharge is called in-lieu recharge.

Recharge Basins. Recharge basins are frequently used to recharge unconfined aquifers. Water is spread over the surface of a basin or pond in order to increase the quantity of water infiltrating into the ground and then percolating to the water table. Recharge basins concentrate a large volume of infiltrating water on the surface. As a result, a groundwater mound forms beneath the basin. As the recharge starts, the mound begins to grow. When the recharge ceases, the mound recedes as the water spreads through the aquifer (Figure B). The infiltration capacity of recharge basins is initially high, and then as recharge progresses, the infiltration rate decreases as a result of surface clogging by fine sediments and biological growth in the uppermost layer of the soil. It has been found that the operation of recharge basins with alternating flooding and drying-out periods maintains the best infiltration rates. Fine surface sediments may occasionally need to be removed mechanically to maintain the effectiveness of recharge basins.

Injection Wells. Injection wells are used primarily to recharge confined aquifers. The design of an injection well for artificial recharge is similar to that of a water supply well. The principal difference is that water flows from the injection well into the surrounding aquifer under either a gravity head or a head maintained by an injection pump (Figure C). As a large amount of water is pushed through a small volume of aquifer near the well face, injection wells are prone to clogging, which is one of the most serious maintenance problems encountered. Clogging can occur in the well perforations, in the well-aquifer interface, and in the aquifer materials. It is suspected that a combination of a build-up of materials brought in by the recharging water and chemical changes brought about by the recharging water are the primary causes of clogging. The most economical way to operate artificial recharge by injection consists of using dual purpose wells (injection and pumping) so that cleaning of the well and the aquifer may be achieved during the pumping period. However, pretreatment of the water to be injected is always necessary to eliminate the suspended matter.

In-lieu Recharge: In some areas, “recharge” may be accomplished by providing surface water to users who would normally use groundwater, thereby leaving more groundwater in place for restoring groundwater levels or for later use. This indirect method of managed recharge is known as in-lieu recharge.

Another widely used method for managed recharge is through release of water into streams beyond what occurs from the natural hydrology (Figure D). Significant amounts of recharge can also occur either intentionally or incidentally from applied irrigation water and from water placed into unlined conveyance canals.

The major purpose of managed recharge is to increase water supply in an area by supplementing the existing groundwater supply. The use of managed recharge to enhance the availability and quality of groundwater has received increased attention in recent years. Numerous managed recharge projects have been implemented in California and others are planned.

PLACEHOLDER Figure A,B,C,D Groundwater Recharge: Natural and Managed

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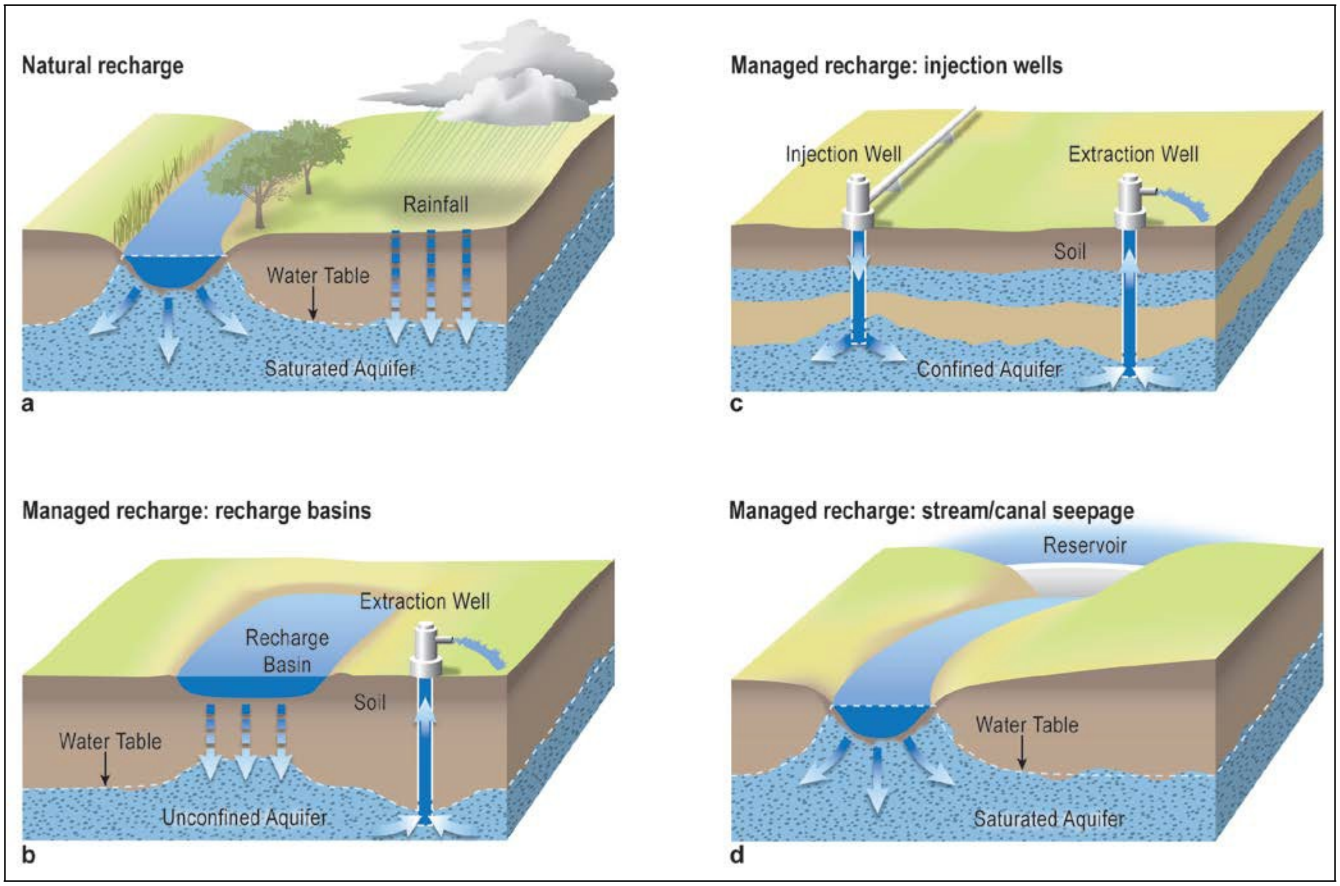
Figure A,B,C,D Groundwater Recharge: Natural and Managed



Box 9-5 Conjunctive Management Case Study 1 in Southern California

Groundwater storage plays an important role in providing a reliable water supply in areas with limited surface water supplies. The Metropolitan Water District of Southern California (MWD) has performed a groundwater assessment study to analyze groundwater use from 1985-2004. The study shows that groundwater provides nearly 40 percent of the total annual water needs within MWD's service area. Between 1995 and 2004, an average of 1.56 million acre-feet (maf) of water per year was produced from the groundwater basins. The study also shows that groundwater production varies as much as 30 percent between the wettest and driest year (MWD 2007).

Groundwater is an important part of MWD's Integrated Water Resource Plan (IRP) for ensuring water supply reliability. To maintain baseline annual production during dry years, the IRP sets out reliability strategies for dry years, and has targeted a dry-year yield from service-area groundwater basins of 275,000 acre-feet per year (afy) by 2010, and 300,000 afy by 2020/25. Because MWD plans for the potential of three consecutive dry years, the yield targets are multiplied by three resulting in dry-year storage targets of 825,000 af by 2010 and 900,000 af by 2020/25 (MWD 2007). These strategies and targets are met by using conjunctive management of surface water and groundwater.

Conjunctive management not only uses groundwater storage for water supply, but also provides recharge and protection to groundwater storage. The 20-year study shows that an average recharge of 758,000 afy resulted from active recharge programs (MWD 2007). About 90 percent of the groundwater recharge — approximately 681,000 afy — was from direct recharge methods (injection or spreading) using imported water, treated recycled water and local runoff, and the remaining 10 percent was from in-lieu recharge (MWD 2007). When surface water supplies are available, MWD encourages in-lieu groundwater recharge by providing financial incentives. As a result of more groundwater recharge facilities becoming available during 1995-2004 as compared to 1985-1994, active recharge using local runoff increased by 7 percent while the proportion of imported water used for recharge declined by 5 percent during the later period (1995-2004). Treated recycled water can be used to prevent salt water intrusion to protect existing groundwater resources and maintain valuable groundwater storage. For example, as part of MWD's conjunctive management, imported water has been spread at Montebello Forebay and injected in the Central Basin of MWD service areas to control seawater intrusion. Recycled water meeting certain water quality standards are also used for irrigation and recharging the groundwater.

The total developed groundwater management capacity in MWD's service area currently includes the following (MWD 2007):

More than 4,300 active production wells (municipal, agricultural, industrial, and private).

- 36 ASR (aquifer storage recovery) wells.
- 5,000 acres of spreading basins.
- 400 acres of water quality wetlands to improve quality of inflows to groundwater.
- 7 seawater intrusion barriers.
- 16 desalters.

Box 9-6 Conjunctive Management Case Study 2 in Northern California

The Santa Clara Valley Water District (SCVWD) is the comprehensive water management agency for the residents of Santa Clara County. It supplies clean and safe water, manages local groundwater basins, implements flood protection projects and provides watershed stewardship. It serves approximately 2 million people — 1.8 million residents and 200,000 commuters — in 15 cities and unincorporated areas in the 1,300-square-mile county (SCVWD 2008).

Similar to many other parts of California, the areas served by the SCVWD also witnessed remarkable agricultural and urban development in the last two centuries. These developments began in the latter half of the 19th century post-Gold Rush era and continued throughout the 20th century. The intense urban and agricultural growth resulted in increased groundwater extraction, which in turn, culminated in groundwater level declines of more than 200 feet and land subsidence of nearly 12 feet. To meet the water needs in the valley, in the late 1920s the SCVWD (or its predecessor) was formed (SCVWD 2009). This set in motion a long succession of facilities construction for surface storage to increase water supply availability and recharge ponds to facilitate conjunctive management through managed groundwater recharge. Since the 1960s, the SCVWD has imported surface water to meet growing demands and reduce dependence on groundwater supplies. Currently, the SCVWD operates and maintains 18 major recharge systems, which consist of both instream and offstream facilities. Local reservoir water and imported water are released in more than 90 miles of more than 30 local creeks for managed instream recharge. In addition, the SCVWD releases locally conserved and imported water to 71 recharge ponds, which range in size from less than 1 acre to more than 20 acres; the total area of the groundwater recharge ponds is more than 300 acres (SCVWD 2012). Through these streams and recharge ponds, the SCVWD recharges the groundwater basin with about 156,000 acre-feet of water each year (Parker 2007). Figure A illustrates how a conjunctive management approach through SCVWD’s recharge programs, imported water deliveries, and treated water programs has resulted in remarkably improving groundwater conditions in the basin (SCVWD 2012).

PLACEHOLDER Figure A Conjunctive Management Case Study 2 in Northern California

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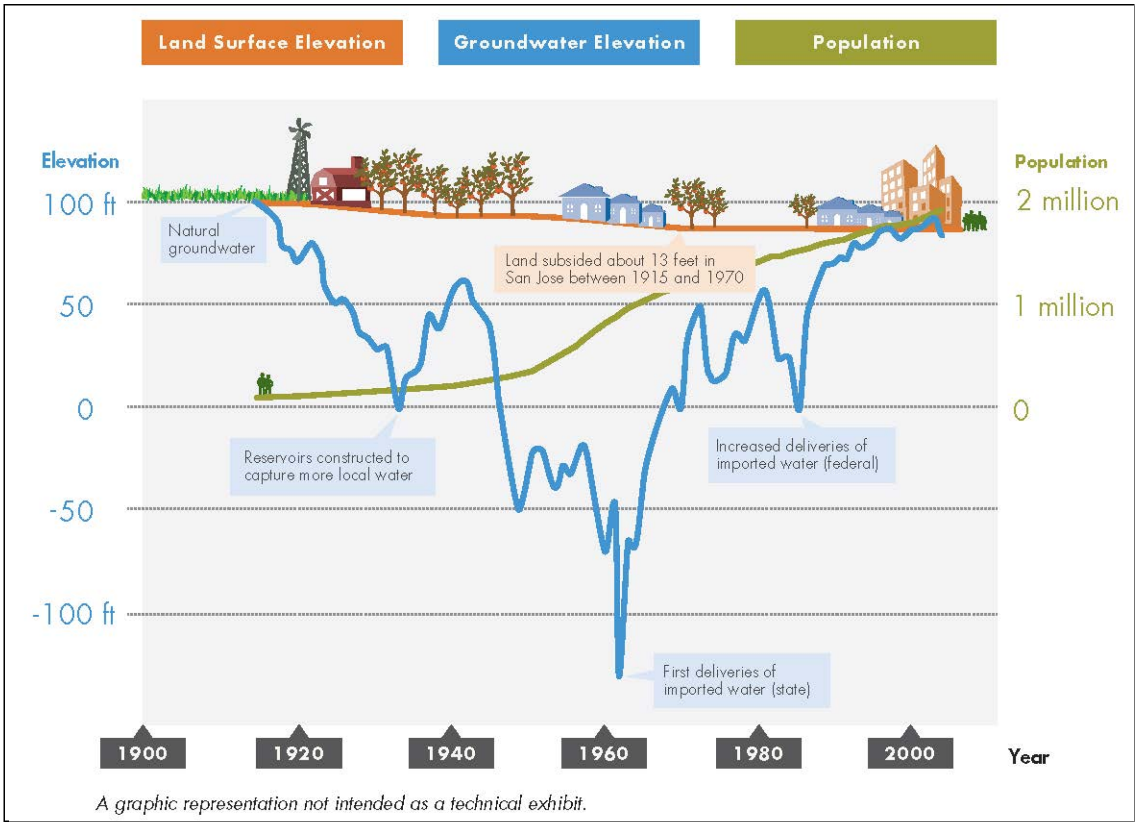
Figure A Conjunctive Management Case Study 2 in Northern California



SCVWD 2012

Box 9-7 Regional Cooperative Arrangements in Northern California

An example of a regional effort that attempts to reach across jurisdictional boundaries is the Four County program. This program revolves around a cooperative Memorandum of Understanding (MOU), originally signed by the counties of Butte, Glenn, Tehama, and Colusa. The MOU, signed in early 2006, outlines how the counties will work together across jurisdictional boundaries on water management issues that are of concern to their collective constituencies. The MOU is accompanied by an addendum, which lays out how information regarding activities in neighboring counties will be conveyed to other counties within the region to ensure that all processes are transparent and each jurisdiction is aware of activities that have the potential to impact their citizenry. Although local ordinances may not cross jurisdictional boundaries, board members in each county have expressed that they do not want to cause harm to their neighbors. The cooperative efforts outlined in the MOU, and its Addendum One, discuss how the various boards intend to communicate and cooperate with each other (Board of Supervisors of Butte, Colusa, Glenn, and Tehama Counties, 2006; 2007). In 2009, Addendum Two added the County of Sutter to the group and Addendum Three documented a commitment by the counties to begin an Integrated Regional Water Management (IRWM) Planning process (Board of Supervisors of Butte, Colusa, Glenn, Tehama, and Sutter Counties, 2009a; 2009b). Addendum Four added the County of Shasta in 2010 and also renamed the IRWM effort to Northern Sacramento Valley IRWM group (Board of Supervisors of Butte, Colusa, Glenn, Tehama, Sutter, and Shasta Counties, 2010).

Box 9-8 Groundwater Overdraft and Conjunctive Management

The two hydrographs below show the response of groundwater levels to differing water management regimes. The first hydrograph (Figure A) shows groundwater levels declining in response to agricultural development in the San Joaquin Valley. Groundwater levels recover somewhat during the wet period of the early 1980s, but continue to decline through the 1980s and 1990s in the absence of a focused conjunctive water management action. The second hydrograph (Figure B) shows a similar groundwater level decline in response to development in southern Yuba County. However, groundwater levels begin to recover in the early 1980s when surface water imports from Yuba County Water Agency began, resulting in conjunctive water management. The hydrograph shows a decline in groundwater levels during the early 1990s drought as surface water imports were curtailed and groundwater was relied upon more heavily. Thereafter, continued conjunctive water management action resulted in the refilling of the South Yuba Groundwater Subbasin, which continues up to present.

PLACEHOLDER Figure A Kings Basin, Fresno County

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PLACEHOLDER Figure B Brophy Water District, South Yuba County

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Figure A Groundwater Overdraft and Conjunctive Management – Kings Basin

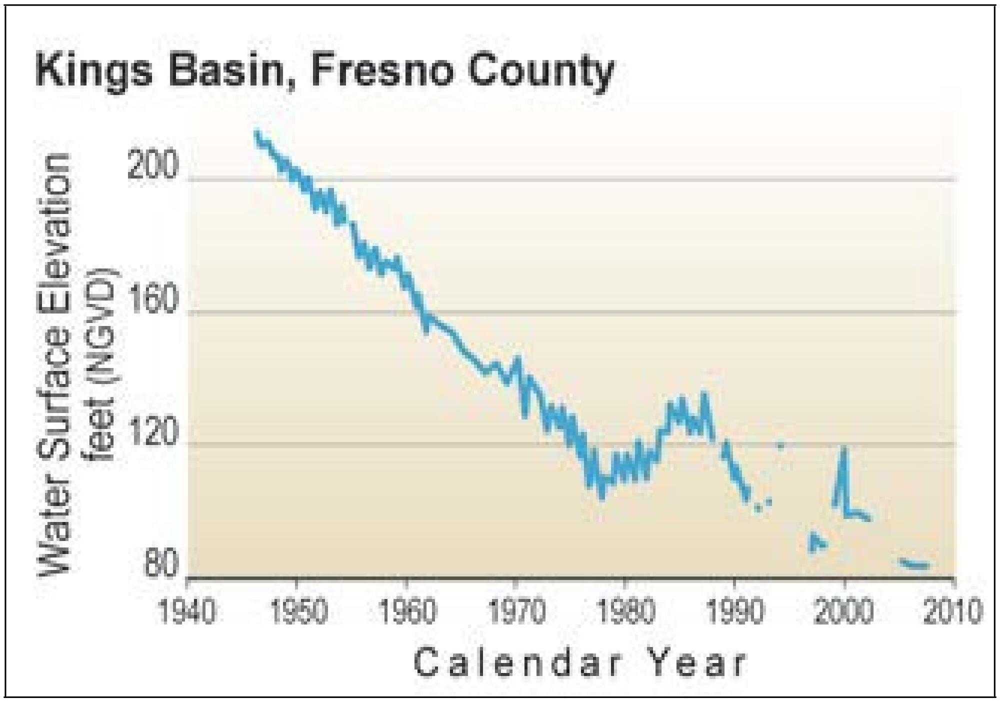
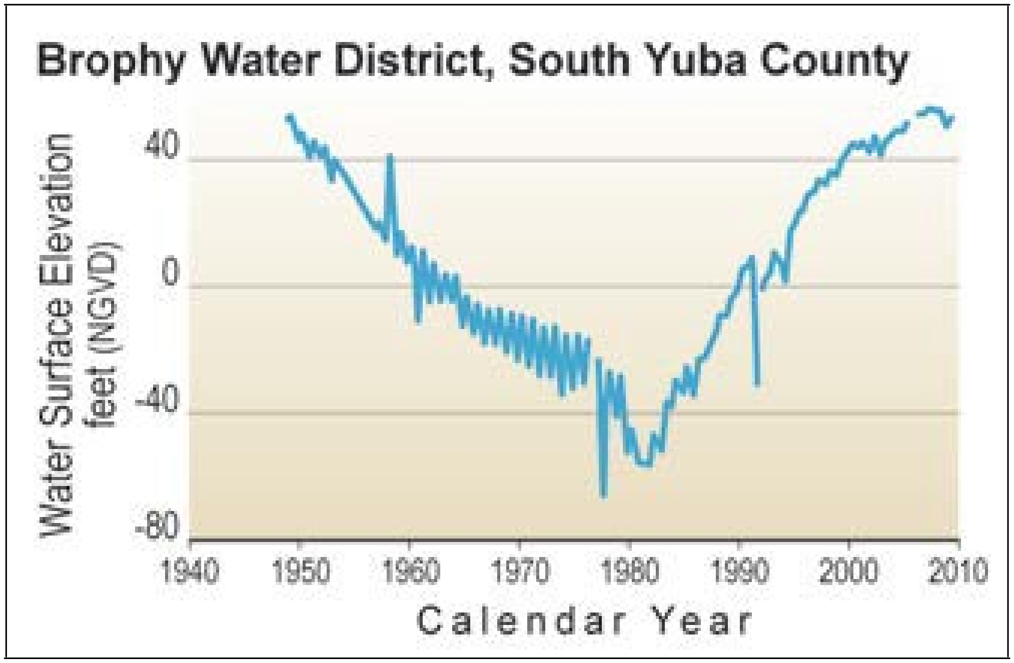


Figure B Groundwater Overdraft and Conjunctive Management – Brophy Water District, South Yuba County



Box 9-9 Components of A Data Collection Program

Data collection programs should include

- Hydrogeologic characterization of the aquifers.
- Changes in groundwater levels.
- Groundwater flow (interbasin flow as well as flow to or from streams).
- Groundwater quality.
- Land subsidence.
- Surface water flow.
- Surface water quality.
- Interaction of surface water and groundwater

Box 9-10 Components of A Groundwater Budget

A groundwater water budget quantifies the amount of water flowing into and flowing out of a groundwater basin, subbasin, and aquifer. Using groundwater monitoring data, streamflow data, and groundwater extraction data that are collected by a local agency, the groundwater budget for each groundwater basin, subbasin, and aquifer under the jurisdiction of the local agency or of an associated basin-wide or regional agency should be developed using the following equation:

Inflow – Outflow = Change in Storage

Inflow:

- Infiltration of precipitation.
- Infiltration from stream channels and unlined canals.
- Groundwater flow into the aquifer.
- Artificial recharge.
- Deep percolation from irrigation.

Outflow:

- Contribution of groundwater to surface water flow out of the basin.
- Groundwater flow out of the aquifer.
- Groundwater extraction (pumping).
- Consumptive use.
- Evapotranspiration.

The most uncertain components in the groundwater water budget should be identified to assess potential sources of error.

Chapter 16. Groundwater/Aquifer Remediation — Table of Contents

Tables

Chapter 16. Groundwater/Aquifer Remediation

Portions of aquifers in many groundwater basins in California have degraded water quality that does not support beneficial use of groundwater. In some areas, groundwater quality is degraded by constituents that occur naturally (e.g., arsenic). In many urban and rural areas, groundwater quality degradation has resulted from a wide range of human (anthropogenic) activities. Groundwater remediation is necessary to improve the quality of degraded groundwater for beneficial use. Drinking water supply is the beneficial use that typically requires remediation when groundwater quality is degraded.

Groundwater remediation removes constituents, hereafter called contaminants, that affect beneficial use of groundwater. Groundwater remediation systems can employ passive or active methods to remove contaminants. Passive groundwater remediation allows contaminants to degrade biologically or chemically or disperse in situ over time. Active groundwater remediation involves either treating contaminated groundwater while it is still in the aquifer (in situ) or extracting contaminated groundwater from the aquifer and treating it outside of the aquifer (ex situ). Active in situ methods generally involve injecting chemicals into the contaminant plume to obtain a chemical or biological removal of the contaminant. Ex situ methods for treating contaminated groundwater can involve physical, chemical, and/or biological processes.

Active groundwater remediation systems that extract, treat, and discharge the treated groundwater to a water body or inject it back into the aquifer are commonly termed “pump and treat” systems. Remediation systems that extract and treat contaminated groundwater for direct potable, irrigation, or industrial use are commonly termed “wellhead treatment” systems. Any wellhead treatment prior to direct potable use must receive a permit from the California Department of Public Health (CDPH).

Contaminated groundwater can come from a many sources, both naturally occurring and anthropogenic. Examples of naturally occurring contaminants include heavy metals and radioactive constituents and also high concentrations of various salts from specific geologic formations or conditions. Climate change resulting in altered precipitation, snowfall patterns, and rising sea levels, all of which exacerbate salt water intrusion and flooding of low lying infrastructure and urban facilities will add new challenges to protect groundwater from contamination. Groundwater can also be contaminated from anthropogenic sources with organic, inorganic, and radioactive constituents from many specific sources and other more diffuse and widespread sources. These anthropogenic sources include industrial sites, mining operations, leaking fuel tanks and pipelines, manufactured gas plants, landfills, impoundments, dairies, septic systems, and urban and agricultural activities. The contaminant having the most widespread and adverse impact on drinking water wells is arsenic followed by nitrates, naturally occurring radioactivity industrial/commercial solvents, and pesticides (see Table 16-1).

PLACEHOLDER Table 16-1 Ten Most Commonly Detected Contaminants at Active Community Drinking Water Wells

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

In the process of extracting groundwater for remediation, the groundwater flows through the aquifer toward the extraction wells where it is removed for treatment. A number of ex situ treatment methods are available to remove contaminants from groundwater and the cost effectiveness of each treatment method should be evaluated prior to selection of a specific treatment method. Ex situ treatment methods can either transfer the contaminant to the atmosphere (directly or after combustion), to an adsorptive media, or to a concentrated liquid waste stream. If a volatile contaminant is transferred from the groundwater to the atmosphere, permits must be obtained from the local air district. If an adsorption media is used, such as granular activated carbon or ion exchange resin, the media may have to be disposed of as hazardous waste and this significantly increases the disposal cost. If the media is regenerated, then the waste residuals which are produced have to be disposed of as hazardous waste. If the contaminant is radioactive or the adsorption media removes radioactive compounds as a co-contaminant, such as uranium, then waste residuals may need to be disposed of as radioactive waste.

Whatever the treatment method listed below (See Table 16-2), it must be suited to the constituent that has contaminated the groundwater. Light, non-aqueous phase liquids (LNAPLs), such as hydrocarbons, float on the surface of the groundwater. Dense non-aqueous phase liquids (DNAPLs), such as perchloroethylene (PCE), have a specific gravity greater than water and sink to the bottom of the aquifer. Other contaminants, such as methyl-tertiary-butyl-ether (MTBE), may be miscible in water and are in solution in the groundwater. Even with LNAPLs and DNAPLs, some of the contaminant dissolves within the groundwater in the aquifer.

PLACEHOLDER Table 16-2 Treatment Methods

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Groundwater Remediation in California

Most groundwater remediation in California involves ex situ groundwater extraction and treatment and does not rely on passive (in situ) remediation, such as biodegradation and natural attenuation. There are approximately 16,000 sites in the state where investigation or remediation of contaminants is ongoing. Regional Water Quality Control Boards (RWQCB), the California Department of Toxic Substances Control, or local agencies have regulatory oversight of these cleanups. About 7,500 of these sites have had a petroleum release from a leaking underground storage tank (UST) system. A petroleum release is usually detected by analyzing for total petroleum hydrocarbons and the more soluble constituents in fuel (benzene, toluene, ethyl benzene, and xylene, commonly called BTEX). In addition to these contaminants, polyaromatic hydrocarbons, naphthalene, and MTBE can be found at former leaking UST sites. Groundwater cleanup at petroleum sites primarily focuses on reduction of BTEX and MTBE because most other components of petroleum are only very slightly soluble in water and do not migrate far from the original source of the leak.

Remediation at petroleum UST sites may involve contaminant source removal (excavation and free-product removal if applicable). Further remediation can include soil vapor extraction, pump and treat, in situ remediation, or a combination of these methods. Pump and treat methodology tends to be expensive and is not employed if other effective remediation options are available. The discharge from a pump and treat system may also require a discharge permit issued by a Regional Water Quality Control Board.

Approximately 800 sites in California use pump and treat systems. About one-third of these are at UST sites where shallow groundwater is typically affected. The treated-flow volumes are typically 10 to 20 gallons per minute.

Most groundwater extraction and treatment remediation systems are located at sites where volatile organic compound (VOC) solvents, such as trichloroethylene (TCE) and PCE, have contaminated groundwater. TCE has been used as an industrial cleaning and degreasing agent and PCE is a degreasing agent and has been the primary chemical used by dry cleaners for decades. Because TCE and PCE are DNAPLs in free phase, they tend to sink to the bottom of aquifers or pool on top of low permeability units, they rarely can be excavated and removed. Both compounds have low solubilities in water but are considered carcinogenic at low concentrations. Remediation systems to extract and treat groundwater contaminated with such solvents may be required. These systems are expensive to operate and may be required for decades. The total volume of water and the fraction of impacted water remain unknown.

TCE and PCE are both being removed from groundwater in the San Gabriel Valley of Los Angeles. More than 30 square miles of the Valley has been designated a federal Superfund site due to commercial and industrial discharges contaminating groundwater. Since the San Gabriel basin aquifer supplies more than 90 percent of the water for the Valley, the treated groundwater is pumped directly into the public water supply distribution system, provided it meets drinking water quality standards. Table 16-3 lists other projects for removal of VOCs.

PLACEHOLDER Table 16-3 Locations of Groundwater Sources of Drinking Water with Selected Detected Contaminants

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Dry cleaning business operations present a significant threat to groundwater quality. Past practices commonly employed by dry cleaners resulted in PCE being discharged onto the ground at the business site or to the sewer. As many as 15,000 dry cleaning facilities have operated in California. Most of these sites, past and present, are small businesses in urban areas. The owners of these facilities typically do not have the resources necessary to fund an investigation and, if necessary, the remediation to remove PCE. Therefore, relatively few of the current and former dry cleaning sites have been investigated. Remediation at dry cleaning facilities typically involves soil vapor extraction. Where groundwater has been affected, pump and treat systems are employed.

Recent studies seem to indicate that operating, non-operating, or poorly designed water wells and possibly oil and gas wells provide conduits whereby chlorinated solvents spread from shallow to deeper aquifers. The burden of dealing with PCE contamination of drinking water often falls on the water purveyor who pumps the groundwater and who may have to discontinue use of the well or install costly treatment equipment. The cost of dealing with the legacy of dry cleaning operations and other sources of chlorinated solvents is estimated to be in the billions of dollars. Treatment systems to remove PCE and other chlorinated solvents from groundwater may need to operate for decades.

Perchlorate is used to manufacture solid propellant for rockets, fireworks, and other uses (e.g., production of matches, flares, pyrotechnics, ordnance, and explosives). Aerospace, military, and flare manufacturing facilities have been primary sources of perchlorate. Perchlorate also occurs naturally and has been found in fertilizer imported from Chile. Perchlorate is highly soluble in water and has adverse health effects at very low concentrations in water. Perchlorate is being removed by either ion exchange or biological treatment from the Bunker Hill, Gilroy-Hollister Valley, Rialto-Colton, Sacramento, and San Gabriel groundwater basins. In the Gilroy-Hollister Valley, the groundwater is being treated to reduce/remove perchlorate prior to delivery to private residences.

Pesticides, especially the agricultural soil fumigants 1,2-dibromo-3-chloropropane (DBCP) and ethylene dibromide, have been found in groundwater in the San Joaquin Valley, Tulare Lake region and Southern California (Riverside and San Bernardino Counties). Wellhead treatment systems have been installed by water purveyors in several communities.

Arsenic is the most widespread contaminant affecting an estimated 587 community drinking water wells (State Water Resources Control Board 2012). All ten hydrologic regions in the state, have community water systems that are affected by arsenic and must treat their affected wells to reduce the arsenic level below 10 micrograms per liter, the current maximum contaminant level (MCL).

Nitrate is considered the second most widespread groundwater contamination problem in California affecting community drinking water wells, primarily due to decades of agricultural application of - nitrogen-based fertilizers. Nitrate-contaminated groundwater can be either treated with reverse osmosis, resin-based processes, or blended with higher quality water before being placed in a water supply distribution system. Several small communities throughout the state have not been able to afford nitrate treatment systems and they must inform residents that sensitive populations, including small infants and pregnant and nursing women, should not consume this untreated drinking water. Accordingly, these small communities should explore other options such as developing a new water source or interconnecting/consolidating with a neighboring community water system. Nitrate is a salt and salt management is addressed as a separate resource management strategy in Volume 3, Chapter 19 Salt and Salinity Management.

One area that is effectively dealing with salt management is the Chino basin in the Santa Ana River watershed. The Chino Basin Optimum Basin Management Program is operating a desalter to remove nitrate that has accumulated in the groundwater from long-term agricultural operations. The treated water is used for potable supply once the nitrate drinking water standard is met. The brine from the desalters is discharged to a “brine line” that feeds into the Orange County Sanitation District’s wastewater treatment plant. Effluent from the treatment plant is discharged to the Pacific Ocean through an outfall.

Septic tank systems can be a localized source of high nitrate contamination in groundwater as well as dairies and other agricultural activities. An estimated 250,000 to 600,000 private domestic wells in California are commonly located near septic systems because building codes allow a minimum of 100 feet of separation between the two. Contaminant plumes from septic tank leach fields have been shown to travel hundreds of feet horizontally in groundwater with little dispersion or dilution of the plume. Domestic wells that are shallow and are not properly sealed are vulnerable to surface contaminants including leachate plumes from nearby septic tank systems.

Potential Benefits

The potential benefits of remediating contaminated groundwater to use the water as a part of the available water supply are:

- There is an additional available water supply that would not be available without remediation.
- Avoiding the cost of buying an alternate water supply.
- Treated groundwater that meets water quality standards may be blended with other water supplies to increase the total available water supply.
- Groundwater from remediation projects and blended supplies that do not meet drinking water or other high water quality requirements may still be available to meet water needs that do not require such high quality water, thus increasing the overall water supply.
- There is a supply that is maintained and used throughout the state to meet up to 40 percent of the state's water demand.
- Less future wellhead treatment costs by preventing contaminant plumes from spreading.
- Use of the remediated aquifer for storage of excess surface water supplies.

Potential Costs

The cost of remediating groundwater includes:

- Cost of characterizing the groundwater or aquifer in terms of the contaminants present and the hydrogeology underlying the contaminant site.
- Capital cost of the remediation system.
- Operation and maintenance costs during the life of the project; remediation may be required for a long time.

Except for petroleum USTs, it is difficult to estimate the cost of cleaning contaminated sites. In 1989, the California Legislature established the Underground Storage Tank Cleanup Fund to reimburse petroleum UST owners for the costs associated with the cleanup of leaking petroleum USTs. The Fund disburses about $200 million annually to eligible claimants. In the 1990s, the cost to clean up an individual UST site typically ranged from $100,000 to $200,000. The cleanup of UST sites contaminated with MTBE costs significantly more, with reimbursements as high as the Fund's limit of $1.5 million per site. As of June 2011, the Fund disbursed more than $3.1 billion to eligible claimants since its establishment.

A site where solvent contamination has reached groundwater may require continuous pump and treat operation for decades and cost millions of dollars. As previously discussed, most sites with solvent discharges (e.g., dry cleaning facilities) have yet to be investigated and remediated.

Based on cost data from the State Water Resources Control Board and the California Department of Public Health, Division of Drinking Water and Environmental Management, total groundwater remediation costs in California, excluding costs of salt management, could approach $20 billion during the next 25 years. The estimate is based on current costs for remediation, estimated future costs for similar remediation, newly discovered contamination, and emerging contaminants. Almost all of these costs are associated with contaminants from previous human activities (legacy contaminants). Current pollution prevention strategies are expected to result in significantly less discharge of contaminants such as petroleum fuel, solvents, and perchlorate.

Major Implementation Issues

Water Quality

Several groundwater quality issues complicate remediation efforts. The type and the concentration of the constituents vary from aquifer to aquifer. Contaminated water associated with historic commercial, agricultural, and industrial chemical discharges may contain a variety of regulated and unregulated contaminants. Non-point source contamination, such as nitrates or elevated levels of boron or salts in agricultural areas, can be widespread in the subsurface and can leach into the groundwater from surface infiltration or rising groundwater levels. Rising sea levels may also increase resource needs to combat seawater intrusion. Contaminated water may be poorly characterized in terms of the contaminants that are present and defining the dimension of the plume is costly. California has a number of Superfund sites where treatment system costs may transfer to the State, which will require additional funding. Emerging contaminants may not be known at current detection levels. The impact of emerging contaminants is also not known. The ability to remediate emerging contaminants is not fully known, although research is being conducted. Reverse osmosis and advanced oxidation processes may prove to be adequate water treatment technologies.

Aquifer Characteristics

California's groundwater basins usually include a series of alluvial aquifers with intermingled aquitards (California Department of Water Resources 2003). Lack of specific knowledge about the geometry and characteristics of an aquifer complicates groundwater remediation. Without this information, it is not possible to develop a cost-effective remediation strategy. How much groundwater is being pumped is unknown. The storage volume of each aquifer and how much of it is contaminated are likewise unknown. The State Water Resources Control Board's Groundwater Ambient Monitoring and Assessment Program (GAMA) was created in 2000. The program's main goals are 1) improving statewide groundwater monitoring and 2) increasing the amount of groundwater quality information available to the public. While this program has made significant progress, much more data is needed to overcome the current lack of knowledge of groundwater hydrogeology, geometry, and characteristics.

Costs of Investigation and Treatment

Costs can impede groundwater remediation. Who will pay, who are the responsible parties, and what is the appropriate share for each responsible party? Site investigation is expensive, particularly when solvents are the contaminant. Groundwater treatment is expensive, and it can take years, decades, or longer to remediate contaminated groundwater sites. Delays in implementing groundwater remediation while the contaminants spread can significantly increase the cost and time required for remediation. This is especially true if long-term litigation is involved to determine responsible parties.

Aside from the UST Cleanup Fund, funding for remediation is provided by responsible parties or parties willing to do the remediation (e.g., city and county agencies). In urban areas, it is often difficult to assign responsibility for the legacy of many decades of discharges of contaminants from disparate sources. Where responsibility can be assigned, responsible parties may not be able to fund investigation and remediation (e.g., dry cleaning business owners). Therefore, wellhead treatment costs are often borne by water purveyors and their customers.

Climate Change

Climate change is likely to create increased groundwater pumping due to reduced surface water flows during summer months. Surface water flows will be reduced because more winter precipitation will fall as rain instead of snow which provides surface water flows when it melts in the summer. As extraction pressures on groundwater basins increase, there may be increased attempts to remediate contaminated aquifers. Climate change will also cause further degradation of groundwater quality in coastal areas due to seawater intrusion from sea level rise.

Adaptation

Developing additional groundwater supplies through remediation will increase California's ability to provide water supplies during drought periods. Making more groundwater basins available for water storage also allows for augmentation of groundwater supplies with recycled or desalinated water. Desalination of coastal groundwater affected by seawater intrusion due to sea level rise may also serve as an adaptation strategy to protect groundwater supplies.

Mitigation

Some of the treatment technologies used for groundwater remediation are energy-intensive. Therefore, groundwater remediation may result in increased GHG emissions. However, if groundwater basins can be restored and replenished, their reliable yield may facilitate less energy-intensive water imports, leading to reduced GHG emissions.

Better Public Education

Better public education and outreach is needed to inform people why source water protection and pollution prevention measures are important and necessary to protect groundwater resources. A better understanding of these measures would enable people to make educated choices and select appropriate actions when their activities may degrade water quality. When groundwater resources are not protected and become impacted by pollution, a community's drinking water supply could require treatment that was previously not needed, significantly increasing the cost to rate payers. Additional information is available in Chapter 18 Pollution Prevention and Chapter 29 Outreach and Education in this volume.

Small Communities

Larger community water systems (CWS) are generally in a better position to deal with contaminated groundwater supplies, because these systems are better able to absorb costs associated with treatment or engineering solutions that address the contamination. These costs are passed onto the rate payers. Small CWS typically lack the infrastructure and economies of scale of larger systems and in some cases cannot afford to treat or find alternative supplies for a contaminated drinking water source. As a result, a small CWS can be more vulnerable to delivering contaminated groundwater to their customers. Some of these communities are small, rural, and disadvantaged and are the focus of environmental justice concerns (State Water Resources Control Board 2012).

Operation and Maintenance Costs for Removing Inorganic Chemicals

When evaluating alternatives to provide safe water to a community, water systems managers should evaluate the operation and maintenance costs associated with any treatment system being considered. For small water systems, a financial analysis should also be completed to assess if the community can afford to operate and maintain a new treatment facility. Annual operation and maintenance costs are typically high for removing inorganic chemicals such as arsenic, nitrate, and perchlorate. In the past the operation and maintenance costs for these treatment facilities has been underestimated, resulting in cost overruns and causing insolvency in some communities. State and federal funding is available to water systems, however most funding programs only cover the capital costs of installing the treatment system, and do not cover the ongoing operation and maintenance costs. There have been instances in which a community installed a treatment plant to remove a groundwater contaminant only to shut down the treatment facility later when it could not afford to operate and maintain the treatment facility.

Use of Extremely Impaired Water Sources for Domestic Water Supply

CDPH considers sources that exceed 10 times a chronic MCL or notification level (NL) or three times an acute MCL or NL or have several different types of contaminants to be extremely impaired water sources and require more investigation and reliable treatment. The investigation involves identifying all known and possible contaminants that could be in the source, a risk assessment in the event of a treatment failure, and the resultant quality of the treated water. The treated water quality objective must take into account the allowable levels of the contaminants and the synergistic effect of similar compounds in the source water. This requires a public hearing to assess public acceptance.

Recommendations

The following recommendations can help prevent pollution, protect groundwater quality, and remediate groundwater where necessary to maintain California's water resources:

1. The Legislature should fund State regulatory agencies to identify historic commercial and industrial sites with contaminant discharges and identify viable responsible parties to investigate and remediate those sites.
2. State agencies should assist local governments and local agencies to implement source water protection measures based on the source water assessments that were completed as of 2003 to protect recharge areas from contamination and prevent future contamination.
3. State agencies should assist local agencies with authority over land use to prevent contamination of recharge areas.
4. Local government and local agencies with responsibility over land use should limit potentially contaminating activities in areas where recharge takes place and work together with entities that propose potentially contaminating activities to develop a sustainable good quality, long-term water supply for beneficial uses.
5. Work with the U.S. Environmental Protection Agency, the Bureau of Indian Affairs, and tribes to accomplish the objectives of recommendations 2, 3, and 4.
6. The State should establish and support research funding at California universities for wellhead treatment systems.
7. The State should establish and support research for detecting emerging contaminants by commercial laboratories.
8. Agencies involved in groundwater cleanup and oversight projects should collaborate and leverage resources and authorities to minimize overlap and improve outcomes.
9. Agencies involved in groundwater cleanup and groundwater purveyors should improve outreach and coordination for regional issues to develop new approaches to aquifer preservation and cleanup.

10. The State should re-evaluate the Water Well Standards and any related oil and gas well standards to ensure the standards spell out how to protect groundwater and drinking water from cross contamination via existing, abandoned, and destroyed wells.

Groundwater and Aquifer Remediation in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions are not consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy is not discussed in the rest of Update 2013), there is no need for this section to appear.]

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Table 16-1 Ten Most Commonly Detected Contaminants at Active Community Drinking Water Wells

Anthropogenic Contaminants	Naturally Occurring Contaminants
Nitrate (as NO3)	Arsenic
Perchlorate	Gross alpha particle activity
Tetrachloroethylene (PCE)	Uranium
Trichloroethylene, TCE	Fluoride
1,2-Dibromo-3-chloropropane, DBCP	
Carbon tetrachloride	

Source: State Water Resources Control Board 2012.

Table 16-2 Treatment Methods

Pump and Treat — Groundwater Remediation
Activated alumina
Biological
Blending
Coagulation/filtration
Granular activated carbon, GAC
Ion exchange, IX
Lime softening
Packed tower aeration (air stripping)
Reverse osmosis, RO
Ultra-violet photo ionization
***In situ* — Aquifer Remediation**
Air sparging
Bio-sparging
Bio-venting
Cosolvents
Electrokinetics
Electron acceptors (nitrate, sulfate, ferric ions)
Electron donors (to degrade chlorinated hydrocarbons)
Fluid cycling
Hydrofracturing/Pneumatic fracturing
Soil vapor extraction
Surfactant enhancements
Thermal enhancements
Treatment walls
Vitrification

Table 16-3 Community Drinking Water Systems that Rely on One or More Contaminated Groundwater Well by Hydrologic Region

Regulated Contaminants												
Hydrologic Region [a]		**NC**	**SF**	**CC**	**SC**	**SR**	**SJR**	**TL**	**NL**	**SL**	**CR**	
Inorganic Chemicals												**Total**
Arsenic	Affected Systems	12	9	21	26	41	58	62	8	41	9	287
	Affected Wells [b]	16	10	36	44	73	120	131	19	119	19	587
Nitrate	Affected Systems	1	4	33	81	9	17	54	0	6	1	206
	Affected Wells	3	10	51	270	9	26	75	0	6	2	452
Perchlorate	Affected Systems	0	0	3	47	1	0	4	0	1	1	57
	Affected Wells	0	0	3	166	1	0	4	0	2	1	177
Hydrologic Region		**NC**	**SF**	**CC**	**SC**	**SR**	**SJR**	**TL**	**NL**	**SL**	**CR**	
Radioactivity												**Total**
Gross Alpha Particle Activity	Affected Systems	0	0	5	47	3	38	46	3	28	13	183
	Affected Wells	0	0	6	89	4	76	78	7	50	23	333
Hydrologic Region		**NC**	**SF**	**CC**	**SC**	**SR**	**SJR**	**TL**	**NL**	**SL**	**CR**	
Volatile Organic Chemicals												**Total**
Tetrachloroethylene (PCE)	Affected Systems	0	1	0	40	7	4	7	1	0	0	60
	Affected Wells	0	2	0	141	10	4	10	1	0	0	168
Trichloroethylene (TCE)	Affected Systems	2	1	0	38	0	1	2	0	0	0	44
	Affected Wells	2	2	0	146	0	2	7	0	0	0	159
Hydrologic Region		**NC**	**SF**	**CC**	**SC**	**SR**	**SJR**	**TL**	**NL**	**SL**	**CR**	
Pesticides												**Total**
1,2-Dibromo-3-chloropropane (DBCP)	Affected Systems	0	0	0	7	0	12	17	0	0	0	36
	Affected Wells	0	0	0	29	0	28	61	0	0	0	118

Source: State Water Resources Control Board 2012.

Notes: [a] Hydrologic regions: NC - North Coast, SF - San Francisco, CC - Central Coast, SC - South Coast, SR - Sacramento River, SJR - San Joaquin River, TL - Tulare Lake, NL - North Lahontan, SL - South Lahontan, CR - Colorado River.

[b] Affected Wells exceeded a Primary Maximum Contaminant Level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment only and did not consider uranium correction.

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Chapter 26. Sediment Management

> The management of sediment in river basins and waterways has been an important issue for water managers throughout history – from the ancient Egyptians managing sediment on floodplains to provide their crops with nutrients, to today's challenges of siltation in large reservoirs. The changing nature of sediment issues, due to increasing human populations (and the resulting changes in land use and increased water use), the increasing prevalence of man-made structures such as dams, weirs and barrages and recognition of the important role of sediment in the transport and fate of contaminants within river systems has meant that water managers today face many complex technical and environmental challenges in relation to sediment management.
>
> International Sediment Initiative, Technical Documents in Hydrology 2011

Sediment in California is a valuable resource when it is properly managed, which results in multiple water benefits, environmental health, economic stability, and coastal safety. Sediment definitions vary among the professional disciplines. Sediment, as reflected in this resource management strategy, is composed of natural materials and used contextually as follows:

1. Geology considers sediment to be the solid fragmented material such as silt, sand, gravel, chemical precipitates, and fossil fragments that have been transported and deposited by water, ice, or wind or that accumulates through chemical precipitation or secretion by organisms, and that forms layers on the Earth's surface. Sedimentary rocks consist of consolidated sediment.
2. The U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) regard sediment as material such as sand, silt, or clay, suspended in or settled on the bottom of a water body.

Sediments can come from anywhere and be just about anything. Organic and inorganic material alike can become bits of matter tiny enough to be picked up and carried along with a moving fluid. Organic sediments are mostly debris from trees, plants, grasses, animals, fish, and their waste products. Inorganic sediments are divided into two main groups; coarse-grained sediments and fine-grained sediments. Coarse-grained sediments are boulders, cobbles, gravel, and sand. Fine-grained sediments are silts and clays. Sediment deposits, like tree rings, can serve as a record of natural history.

A further important distinction is whether they are clean sediments or contaminated sediments, as this greatly affects the manner in which they can be used as beneficial material or if they must be isolated from their surrounding environment. For this resource management strategy, the term *sediment* will mean *clean sediment*, and if the *sediment is contaminated*, the term *contaminated sediment* will be used.

Debris management is also associated with sediment management. Debris may contain sediment, but it is not entirely composed of sediment. Likewise, debris is not trash. Debris consists of fragmented materials that are organic (trees, brush, and other vegetation) and are inorganic (soil, rocks, boulders, and other sediment) that is primarily moved by flood waters. Large woody material is key to sorting material and creating scours and pools. Pools provide an important habitat for juvenile fish, as well as refugia during flood events. Large woody debris also creates turbulences that clean spawning gravels. Debris basins are built in areas subject to debris flows to save lives and protect property. Trash consists of discarded human-made products (e.g., litter) that sometimes comingles with debris. Trash racks are typically placed on critical equipment, such as pump stations, to prevent mechanical failure caused by litter build-up during a flood.

Debris management is critical in flood management and includes the post disaster removal of materials — natural and human-made — generated by a flood and extreme weather events. Debris in these situations can range from boathouses to gravel bars to zoo enclosures.

While debris management is linked, this chapter focuses primarily on sediment management. Sediment management tools are essential for successful integrated water management as the presence or absence of sediment has a significant impact on water and its beneficial uses.

Sediment Management

Sediment, like fresh water, is limited in supply and is a valuable natural resource. Sediment management is critical for the entire watershed, beginning with the headwaters and continuing into the coastal shores and terminal lakes. However, from a human perspective, sediment has a dual nature; it is desirable in some quantities and locations and unwanted in others. Sediment contributes to many positive purposes and is also used for many positive purposes such as beach restoration and renewal of wetlands and other coastal habitats. Sediment is also needed to renew stream habitat. Spawning gravels need replenishment, and fine-grained sediment is needed to maintain, enhance, or restore good quality native riparian vegetation and wetlands. Flood deposits of fine-grained sediment into floodplains are the source of much of California's richest farmland. Sediment, particularly sediment adjacent to hot springs, has been considered for centuries to hold healing properties. Sediments can also be used for habitat restoration projects, beach nourishment, levee maintenance, and construction material.

The key to effective water-sediment management is to address excessive sediment in watersheds. Potential impacts of excessive sediment generally associated with fine-grained sediments are:

- Clouding water, degrading wildlife habitat, forming barriers to navigation, and reducing storage capacity in reservoirs for flood protection and water conservation.
  Increasing turbidity and suspended sediment concentrations and negatively affecting the ability of surface water to support recreation, drinking water, habitat, etc.
- Affecting sight-feeding predators' ability to capture prey.
- Clogging gills and filters of fish and aquatic invertebrates, covering and impairing fish spawning substrates, reducing survival of juvenile fish, reducing fishing success, and smothering bottom dwelling plants and animals.
- Physically altering streambed and lakebed habitat.

Other excess sediment issues sometimes include:

- Reducing the hydraulic capacity of stream and flood channels, causing an increase in flood crests and flood damage. Sediment can fill drainage channels, especially along roads, plug culverts and storm drainage systems, and increase the frequency and cost of maintenance.
- Decreasing the useful lifetime of a reservoir by reducing storage capacity. This loss in storage capacity affects the volume of stored water available for municipal supplies and the volume available for floodwater storage.

- Higher maintenance costs and potential problems associated with excess sediment in shipping channels, harbors, and drainage systems and disposing removed sediment. Excess sediment that accumulates in ports, marinas along the coast, working rivers and recreational lakes, affects boating and shipping activity and can lead to demands for dredging to restore or increase depths.

Toxic pollutants, including those from stormwater, may also be adsorbed onto sediments. Another key to effective water-sediment management is to address this contaminated sediment in watersheds. Contaminated sediment has a direct effect on aquatic life. Concentrated pollutants can greatly impair water quality if they are remobilized back into the environment. Potential contamination issues are:

- Direct effects on aquatic life.
- Toxic pollutants from stormwater may also be adsorbed onto sediments. Contaminates in sediments can bioaccumulate or magnify in the food chain and cause problems for aquatic plants, animals, and humans.
- Impaired water bodies.
- Nutrients such as nitrates, phosphorous, potassium, and toxic contaminants, such as trace metals and pesticides, when resent, are associated with fine-grained sediment. In some cases, suspended sediment particles increase bacterial growth, which can concentrate these nutrients.

Management of watershed sediment location and movement can also have positive and negative consequences, as well as large economic and ecological consequences. For example, excess sediment in shipping channels may cost ports millions of dollars in delayed or limited ship access, while in other locations insufficient sediment deposits could result in the loss of valuable coastal wetlands, beaches, recreation, and tourism, which are worth billions of dollars.

Sediment processes are important components of the coastal and riverine systems integral to environmental and economic vitality. Sediment management relies on knowledge about the context of the sediment system and forecasts about the long-range effects of management actions when making local project decisions. A major goal in sediment management is to stabilize and/or restore the watershed for sediment production meaning mimicking natural sediment production, not eliminating it, and thus provides the various ecological and beneficial uses. Watershed stability is determined by performing geomorphic assessments of the waterways within that watershed. Then, for the produced sediment, use this sediment most beneficially throughout the watershed.

Numerous factors including geology, climate, development and population, and the location of littoral cells affect sediment management issues. Littoral cells are self-contained sections, or a compartment, along the coast wherein sand enters (streams, cliff erosion) temporarily resides (beaches), and exits (submarine canyons, offshore shelf). These factors vary significantly throughout the state. For that reason, sediment is best managed on a watershed-littoral cell basis, taking into consideration the sediment source and needs from the top of the watershed to the coast where sediment will ultimately end. Adjacent littoral cells do not typically share sand whereas fine-grained sediments exhibit different behavior along the coast (e.g., turbidity plumes cross over cell boundaries). Regional sediment management recognizes sediment as a valuable resource and supports integrated approaches to achieve balanced and sustainable solutions for sediment related needs.

Management Framework

The Regional Water Quality Control Boards (RWQCB) provide regulatory oversight for transport of course-grained sediment to the coast and management of excessive watershed sediments. The USACE, EPA, State Lands Commission, and San Francisco Bay Conservation Development Commission also have authority for aspects of sediment management and dredging in their respective jurisdictions.

A stream that has excessive erosion, suspended sediments, and/or sedimentation may be determined by a RWQCB to be unable to support its designated beneficial uses and may be listed as impaired under the Section 303(d) of the Federal Clean Water Act. The RWQCBs are working to reduce excessive sediment within streams when it occurs within their regions through the use of total maximum daily load (TMDL) requirements. The *National Water Quality Inventory: Report to Congress, 2004 Reporting Cycle* , shows that sediment is a major water quality problem in the nation's streams.

PLACEHOLDER Box 26-1 [explains beneficial uses from the Water Board's perspective]

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Partnerships have been formed throughout California to manage sediments better in a variety of ways. In San Francisco, the USACE, the EPA, the Regional Water Quality Control Boards, the San Francisco Bay Conservation and Development Commission (BCDC), and the State Lands Commission formed a partnership to address the disposal and beneficial reuse of sediment dredged from the San Francisco Bay. The Long-Term Management Strategy for the Placement of Dredged Sediment in the San Francisco Bay Region (LTMS) reduces in-bay aquatic disposal of sediments in favor of reusing that sediment beneficially in habitat restoration projects, levee maintenance, agricultural enhancement, and construction projects. LTMS emphasizes using sediment as a resource while simultaneously reducing impacts from aquatic disposal in the bay. This program coordinates and manages approximately 110 maintenance dredging projects, regulated by eight state and federal agencies under a common set of goals and policies. The LTMS policies and management practices also enable streamlining the permitting process, including coordinating programmatic consultations with the resource agencies, standardizing testing protocols, and increasing predictability for organizations with permits. There is also a quasi-LTMS process in the Delta.

On a statewide basis, the California Coastal Sediment Management Workgroup (CSMW) was established to develop regional approaches to restore coastal habitats, such as beaches and wetlands, that have been impacted by human-induced alterations to natural sediment transport and deposition through federal, State, and local cooperative efforts. CSMW is comprised of many State, federal, and local interests whose mission is to identify, study, and prioritize regional sediment management needs and opportunities along the coast and provide this information to resource managers and the public.

The CSMW was formed in response to concerns that shore protection and beach nourishment activities were being conducted on a site-specific basis, without regard to regional imbalances that could exacerbate the local problem. The consensus was that a regional approach to coastal sediment management is a key factor in developing strategies to conserve and restore California's coastal beaches and watersheds. The CSMW's main objectives include reducing shoreline erosion and coastal storm damages, restoring and protecting beaches and other coastal environments by reestablishing natural sediment supply from rivers, impoundments and other sources to the coast, and optimizing the use of sediment from ports, harbors, and other opportunistic sources.

The CSMW oversees the development of the California Coastal Sediment Management Plan (SMP) (http://www.dbw.ca.gov/csmw/smp.aspx). The SMP will identify and prioritize regional sediment management (RSM) needs and opportunities along the coast, provide this information to resource managers and the public, and streamline sediment management activities. A series of Coastal RSM Plans (strategies) are being developed for one or more individual littoral cells focusing on issues specific to each region. Tools, documents, and RSM strategies developed to date are available on the CSMW Web site (www.dbw.ca.gov/csmw).

Sediment Management and Flood Management

Sediment management is a key consideration in flood management. Sediment deposition in the channel or floodplain can decrease flood capacity/flood management. Sediment-starved channels can increase velocity, which can increase flooding.

When a river breaks its banks and floods, it leaves behind deposits of sediment. Sediment concerns consist of more than erosion. Overtopping can result in depositions in the channel or in the floodplain, which affect flood management. These depositions can reduce flood capacity. Rivers can also erode their banks and potentially erode levees or flood control structures. These gradually build up to create the floor of floodplains. Conversely, floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. These are accumulations of sand, gravel, silt, and/or clay, and are often important to aquifers because the water drawn from them is pre-filtered compared to the water in the river.

Geologically ancient floodplains are often represented in the landscape by fluvial terraces. Fluvial processes are the movement of sediment, organic matter, and erosion that deposits on a river bed, and the land forms this creates. Fluvial terraces are old floodplains that remain relatively high above the present floodplain and indicate former courses of a floodplain or stream.

When floodplains are separated from the water source, through levees or other means, the natural process of equilibrium, which elevates the land through sediment deposits, is interrupted. This alters the historic flooding and sediment distribution patterns. In some cases, sediments remain within the restrained channel, settling and reducing the capacity of the channel, and increasing the likelihood of flooding. In many cases, this is avoided by dredging the channel and then mechanically depositing the sediment in desirable locations.

Alluvial fans are another form of flood sediment deposit. Over geologic time, sediment, debris, and water emerge from the mountain front along different courses. Alluvial fans are found where these materials gather speed in narrow passages then emerge into less confined areas where they can change course. A number of factors contribute to the severity of these flows including the degree of steep grades to flatter grades. Sediment, debris, and water spill out in a fan shape, settling out and depositing on its way. The channels on these fans range from shallow to very deep (several meters) with a flow speed that can move boulders that are sometimes taller than a house. These conditions are found in California at mountain fronts, in intermountain basins, and at valley junctions. Alluvial fans are found where sediment loads are high, for example, in arid and semiarid mountain environments, wet and mechanically weak mountains, and environments that are near glaciers.

Historic Context

A combination of both natural and human-made impacts to California waterways has led to today's sediment management challenges and solutions. Historically and prior to California becoming a state, sediment flowed naturally from the mountains into streams, meadows, rivers, lakes, and the ocean. California Native Americans understood the seasonal and climate impacts of waterway flows and drought which impacted levels of sediment. This environment provided a wide variety of flora and fauna that was useful as food and tool manufacturing sources for native people (Theodratus 2009). As Europeans encountered the territories that became California, they altered this landscape by dredging passages of interior waterways for navigation, and captured a reliable water supply for their new settlements.

In addition to alterations to facilitate agrarian settlements, many of California's current sediment management issues also can be traced to historic gold dredge activities in the 1850s. California's Central Valley and Bay-Delta waterways experienced significant alteration caused by billions of cubic yards of sediment and debris sent downstream from hydraulic mining operations. Court action stopped these activities. However, impacts from these activities continue today. Ditches used for mining are still in use for agriculture and public water supply. The channel infilling that occurred in many of the gold bearing streams is still in evidence and many streams, such as the Feather and Yuba rivers, and these are still adjusting their watercourses 150 years later.

Some early reservoirs (Clementine, Englebright, Camp Far West) were initially built to capture the sediment. There are still millions of tons of mining debris remaining on the floodplain. The U.S. Geological Survey has measured the amount of sediment entering the San Francisco Bay from numerous tributary streams and determined the historic changes in sediment yield over the long term. Today, scientists have concluded that much of the hydraulic mining sediments have moved through the Delta and potentially through much of San Francisco Bay. However, multiple institutions, laws, and human settlement patterns created during this era remain, and, ironically, wetlands that were established as a result of the inundation are now undergoing erosion.

Beyond the Delta and Central Valley, impacts from historic and current road building and land management practices continue to contribute to existing problems. Landslides resulting from natural and human processes are a major producer of sediment.

Additional system alterations also occurred as dams and channels were built for both water supply and flood protection. More and more structures changed what had been the natural hydrology, which then altered system stability for sediments. As a result, the normal function of waterways has also been changed to produce sediment, move it through the watershed, with some settling occurring in low areas that are now typically used for farming or urbanization, and ultimately depositing it at the shoreline, replenishing the coastline or terminal lakes. In addition to sediment being trapped in flood control structures, peak velocities during storm events has also been reduced, limiting the ability of the stream to move coarse-grained sediment downstream to the coast.

Many ports and harbors were constructed in the 1940s and 1950s along the coastline without regard to the natural process of sand transport along the coast. This natural transport activity has been interrupted by the entrance channels to the harbors, such that the sand being transported down the coast is deposited instead within the entrance channels. This shoaling results in shallower depths and potentially hazardous conditions within the channel, necessitating the ongoing dredging of the channels to restore function and safety. Beneficial reuse of the dredged material is an opportunity for regional sediment management.

Due to the desire to work, live, and play along the coast, significant development along the shoreline has occurred without consideration of the impacts to such development by natural processes. As a result, much of the shoreline has been armored to reduce erosion at specific locations to protect specific structures. Such armoring has reduced the natural supply of sediment to the beaches from bluff erosion. This causes beaches to become more narrow and there is an associated loss of habitat and access from passive erosion and accelerating erosion of adjacent areas due to wave focusing.

Land use has also altered patterns of natural alluvial fans. As one example, much sediment in Los Angeles County is the result of the naturally erosive mountains. The San Gabriel Mountains are mostly undeveloped because they are within the Angeles National Forest. Other mountain ranges (Santa Monica, Verdugos, Puente Hills) also have large areas of undeveloped land. The basins and valleys below these mountains are large, relatively flat, alluvial plains. The depth of the sediment deposits indicates that a significant portion, and possibly the majority, of the sediment are from the adjacent mountains.

Many Los Angeles County residents/businesses moved into these flat alluvial plains. The original inhabitants, impacted by frequently fluctuating watercourse alignments caused by high amounts of sediment deposition, wanted more stable river/stream alignments for use and recharge. This situation led to the construction of dams, debris basins, channels, and spreading grounds in Los Angeles County to serve agricultural and urban areas. Farms and subdivisions were then located in naturally occurring sediment disposal areas Many of those inhabitants are unaware that they are sitting on still-active alluvial fans.

Management Approach

Understanding the cumulative impacts of all past, present, and proposed human activities in a watershed (and/or littoral cell) is important in predicting the impacts of sediment on surface waters. Sediment management in water bodies typically focuses on addressing three issues:

1. The type and source of sediment.
2. The systems transporting sediment.
3. The location where sediment deposits.

Management actions are tailored to the situation, depending on the location where the management actions will occur and whether the management actions involve a natural environment (rivers, streams, creeks, and floodplains) or a built environment (water control structures, flood levees, dams).

Source Management

Source management is preventing soil loss and adverse sediment flows from land use activities that may, without proper management, cause erosion and excessive sediment movement. Routine source management activities prevent or mitigate excessive sediment introduced into waterways due to recreational use, roads and trails, grazing, farming, forestry, and construction. Excessive flows affecting erosion and sedimentation may also result from land-based events such as extreme weather, fires, high water volumes, wind, and other factors.

Road construction and maintenance in or near streams can also be a source of sediment. Photo 26-1 is a picture of the Caltrans I-5 Antlers Bridge realignment project on Shasta Lake. The photo shows the dramatic erosion and sediment controls required for a massive cut and fill project that threatens surface waters (Central Valley Regional Water Quality Control Board 2011).

PLACEHOLDER Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Another transportation related source is off-highway vehicle (OHV) use. OHV is a popular form of recreation in California. State, federal, local agencies, and private entities provide recreational areas for this purpose. These OHV recreation areas are required to implement a range of sediment management and stormwater Best Management Practices (BMP) to protect water quality. Unfortunately, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted stormwater. With limited resources, maintaining and policing these areas can be a challenge.

Sedimentation can be a problem in the construction and operation of many mines. Increased potential for erosion and sedimentation at mines are related to mine construction and facility location. Tailings dams, waste rock and spent ore storage piles, leach facilities, or other earthen structures are all potential sources of sedimentation to streams. Road construction, logging, and the clearing of areas for buildings, mills, and process facilities can expose soils and increase the amount of surface runoff that reaches streams and other surface water bodies.

Agencies and Organizations Involved in Source Sediment Management

Many agencies and organizations contribute to sediment source management as land managers, land use planners, advisors, and regulators, and through training, technical and financial assistance, and promotion of good policy. An overview of some of those key entities and their activities are in Table 26-1.

PLACEHOLDER Table 26-1 Agency Roles and Activities in Sediment Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Sediment Transport Management

Sediment, like water, flows downstream and supports both shorelines and habitats at the end of the line. Rivers and streams carry sediment in their flows. There is a range of different particle sizes in the flow. It is common for material of different sizes to move through all areas of the flow for given stream conditions. The sediment can also be in a variety of vertical locations within the flow, depending on the balance between the upwards speed on the particle (drag and lift forces), and the settling speed of the particle.

Sediment, primarily sand, also moves along the coastline as littoral drift. This "river of sand" is driven by wind and waves interacting with the shoreline and its orientation. Sand enters the littoral cell from streams and rivers, moves downcoast picking up additional contributions from eroding bluffs, and leaves the littoral cell when it reaches a submarine canyon. Some sand is also lost to the offshore during large storm events. The sand resides temporarily along the coast as beaches, and fluctuations in the supply/loss of sand to the system will affect beach widths.

PLACEHOLDER Box 26-2 Definitions

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Sediment transport management is the process of introducing or leveraging natural functions that create optimal sediment transport. This involves managing the speed and flow of the sediment conveyance and the natural or built structures to achieve a properly distributed balance of sediment types in the habitat. Properly managed transport of sediments will result in the optimal sediment deposition.

For example, sand bypass structures in flood control channels are starting to be used. Such structures placed into flood channels allow the coarse-grained sediments to be diverted to a settling pond where they can be excavated and used for construction, while the fine-grained sediments are diverted to a wetland where they add to the size of the wetland. More information on this method can be seen at http://www.ocwatersheds.com/Documents/wma/LaderaRanch_HNouri.pdf and http://www.ocwatersheds.com/Documents/wma/Integrated_Mgmt_of_Stormwater_Sediment_and_Pollutants_in_Ladera_Ranch.pdf.

Sand transport management along the coast includes dredging harbor entrance channels that have become clogged with the migrating sands, and transporting the dredged materials to some other location. In some areas, sand traps have been constructed to facilitate such transport prior to the sands entering the harbors. Elsewhere along the coast, retention structures (e.g., groins) have been constructed to slow down the alongshore transport, maintaining beach widths for longer periods of time. If the area upcoast of the groins is not properly filled with sand, beaches downcoast of the groins can experience accelerated erosion.

Sediment Deposition Management

The goal of sediment deposition management is to achieve optimum benefits from sediment deposits and mitigate negative impacts. As noted previously, properly distributed sediment has numerous beneficial outcomes such as:

- Fine-grained sediments supporting existing habitat and adapting to sea level rise.
- Gravel remaining in rivers and streambeds for habitat and riverbed stability.
- Sand sustaining beaches both for recreation and habitat.
- Fine silts and clays introducing nutrient rich materials and nutrient cycling.
- Deposits creating buffers, particularly offshore, that reduce climate change and storm surge impacts. Coastal areas that benefit from sediment can also include offshore mudbelts.

Deposition management also includes techniques to prevent and mitigate the negative aspects of excessive sediment including:

- Siltation creating an impact the capacity of floodways, reservoirs, and water supply systems including dams.
- Siltation creating unsafe shipping and transportation channels and creating an impact on other commercial and recreational navigation.
- Siltation inundating wetlands.
- Deposition filling pools and embed riffles, which reduces stream habitat.

The USACE maintains the primary federal permitting and operational responsibility over waterway and navigational dredging, flood control, and the operation of many dams. The EPA oversees USACE's implementation of its Clean Water Act and Marine Protection, Research, and Sanctuaries Act (MPRSA) responsibilities, as well as establishing water quality criteria and implementing certain TMDLs. Additionally, the U.S. Bureau of Reclamation maintains a significant federal role in maintenance, construction, and even deconstruction of dams.

The California Coastal Commission, Department of Water Resources, the State Lands Commission, State Water Resources Control Boards, and BCDC serve as State counterparts. Additional federal and State resource agencies are responsible for fisheries and recreation.

Dredging and Sediment Extraction

Dredging is an excavation activity or operation usually carried out, at least partially underwater, in shallow water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. This technique is often used to keep waterways navigable.

Other forms of sediment extraction can be completed by various methods including scraper, dragline, bulldozer, front-end loader, shovel, and sluicing. Sluicing is a sediment removal method that employs water flow to remove smaller particle sediment (i.e., sands and silts) to remove sediment accumulated in reservoirs. Sluicing is one of the two methods the Los Angeles County Flood Control District has used since the 1930s to remove sediment from its reservoirs.

Extraction methods are often used to maintain the capacity of flood and water supply infrastructure and mine sediment, sand, and gravel for multiple purposes such as commercial construction, levee stabilization, and environmental restoration. Determining how the extracted sediment will be managed involves a variety of factors including environmental acceptability, and technical and economic feasibility.

Dredging is a critical sediment deposition management activity supporting commercial shipping, homeland security, fishing, recreation, and environmental restoration. Detailed descriptions of dredging equipment and dredging processes are available in Engineer Manual (EM) 1110-2-5025 (U.S. Army Corps of Engineers 1983; Houston 1970; Turner 1984).

In San Francisco Bay alone, dredging facilitates a substantial maritime-related economy of more than $7.5 billion annually. By necessity, maritime facilities are located around the margins of a bay system that averages less than 20 feet deep, while modern, deep-draft ships often draw 35 to 50 feet of water or more. In order to sustain this region's diverse navigation-related commercial and recreational activities, extensive dredging — in the range of 2 to 4 million cubic yards (mcy) per year — is necessary to maintain adequate navigation channels and berthing areas. Effective management of the large volumes of dredged material generated throughout this estuary is both a substantial challenge and an opportunity for beneficial reuse. Both are addressed by the Long Term Management Strategy for Dredging (see http://www.bcdc.ca.gov/pdf/Dredging/EIS_EIR/chpt3.pdf) and the interagency Dredged Material Management Office. Navigational dredging in Southern California is similarly managed to encourage beneficial reuse wherever possible under the Los Angeles Basin Contaminated Sediment Management Strategy's Master Plan and the interagency Dredged Materials Management Team.

There are some known issues related to dredging and other forms of sediment extraction:

- Dredging and sediment extraction can directly impact water quality, habitat quality, and contaminant distribution. Operations may reduce water quality by introducing turbidity, suspended solids, and other variables that affect the properties of the water such as light transmittance, dissolved oxygen, nutrients, salinity, temperature, pH, and concentrations of trace metals and organic contaminants if they are present in the sediments (see http://www.spn.usace.army.mil/ltms/chapter3.pdf).
- Depending on the location of the dredging, deepening navigation channels can increase saltwater intrusion since saline water is heavier than freshwater, potentially causing an impact to freshwater supplies and fisheries (e.g., deepening of the Sacramento and Stockton deep water ship channels in the Delta). Dredging can also increase saltwater intrusion into groundwater aquifers (e.g., the Merritt Sand/Posey formation aquifer in the Oakland Harbor area), with consequent degradation of groundwater quality in shallow aquifers.
- Sediment removal operations may also reintroduce contaminants into the water system by re-suspending pollutants. Metal and organic chemical contamination is widespread in urban shipping channels due to river runoff and municipal/industrial discharges. Chemical reactions that occur during removal may also change the form of the contaminant. These chemical reactions are determined by complex interactions of environmental factors, and may either enhance or decrease bioavailability, particularly those of metals. At the same time, dredging can aid in overall reduction of pollutants in a water body when contaminated sediments are removed from the system or sequestered in habitat restoration projects.

Many things have been done to address these existing issues. There are pre-dredging and real-time monitoring programs that have been developed to test the quality of sediments to be dredged, and there are alternative disposal sites where different quality sediments can be taken. Time windows for when some dredging can occur have been established to accommodate certain ecological cycles. Upland sediment disposal sites can be designed to mitigate for many contaminants, and extremely contaminated sites can be capped in-place underwater. Evaluation of dredged material for ocean disposal under the Marine Protection, Research, and Sanctuaries Act (MPRSA) relies largely on biological (bioassay) tests. The ocean testing manual, Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual), commonly referred to as the Green Book, provides national guidance for determining the suitability of dredged material for ocean and near-coast disposal. Evaluation of dredged material for inland disposal under the Clean Water Act (CWA) relies on the use of physical, chemical, and/or biological tests to determine acceptability of material to be disposed. The inland testing manual, *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual*, provides national guidance on best available methods.

Beneficial reuse of dredged and extracted sediments can solve what can otherwise be a dilemma of how to dispose of dredged and extracted sediments as a waste by repurposing it in a variety of ways. These can be used to raise subsided lands to allow restoration as an agricultural supplement and to support levees. When this occurs, the economics of disposal may be altered. In particular, the initial cost to the dredger for sediment removal and placement may be increased. For example, reusing the sediment may require different equipment, the transportation distance to the reuse site may be greater than to the traditional disposal site, and the amount of time needed to complete the dredging work may be extended. In addition, sediment is a public trust asset and thus it is subject to State mineral extraction fees and other restrictions. Because public trust lands are held in trust for all citizens of California, they must be used to serve statewide, as opposed to purely local, purposes.

Dam Retrofit and Removal

Dams are an important part of California's water and flood management and will remain so for the foreseeable future. Sediment deposits naturally behind dams and reservoir sediment management includes a range of options including sluicing of sediment, dredging, redesign, retrofit, and removal.

Dam retrofit is an option for deposition management. The Natural Heritage Institute (NHI), a non-governmental and non-profit organization, has been a pioneer in this area. They are investigating the feasibility of re-operating some dams in order to restore a substantial measure of the formerly productive floodplains, wetlands, deltas, and estuaries located downstream in ways that do not significantly reduce — and can sometimes even enhance — the irrigation, power generation, and flood control benefits for which the dams were constructed.

Dam removal is sometimes a result of sediment management, or it creates a need for sediment management. As noted earlier, sediments trapped behind dams or in reservoirs may require periodic sediment removal to maintain function and capacity. However this is sometimes extremely challenging due to the facility's location and the lack of disposal or beneficial reuse opportunities at nearby locations. In recent years, there has been increased interest in dam removal for sediment-related reasons, such as the loss of capacity of the facility to hold water due to accumulated sediment. In other cases, the reasons may be unrelated, such as a need to upgrade hydrogenation or improve a stream fishery. Analysis of dam removal proposals requires significant discussion of sediment deposition management. Management of sediments behind such dams has been an important element of negotiations related to dam decommissioning.

Regional Sediment Management

Regional Sediment Management (RSM) refers to the practice where sediment is managed over an entire region. Managing sediment to benefit a region potentially saves money, allows use of natural processes to solve engineering problems, and improves the environment. RSM as a management method:

- Includes the entire environment from the watershed to the sea.
- Accounts for the effect of human activities on sediment erosion as well as its transport in streams, lakes, bays, estuaries, and oceans.
- Protects and enhances the nation's natural resources while balancing national security and economic needs.

RSM is an approach for managing projects involving sediment that incorporates many of the principles of integrated watershed resources management, applying them primarily in the context of coastal watersheds. While the initial emphasis of RSM was on sand in coastal systems, the concept has been extended to riverine systems and finer materials to completely address sources and processes important to sediment management. It also supports many of the recommendations identified by interagency working groups for improving dredged material management. Examining RSM implementation through demonstration efforts can provide lessons not only for improved business practices, techniques, and tools necessary for managing resources at regional scales, but also on roles and relationships that are important to integrated water resources management.

This is a growing concept nationwide which also has economic benefits. The USACE has a primer on Regional Sediment Management at http://www.spur.org/files/u35/rsmprimer.pdf.

More information about RSM can be found in the American Society of Civil Engineers written Policy Statement 522, on Regional Sediment Management at http://www.asce.org/Content.aspx?id=8638.

Connections to Other Resource Management Strategies

Many other resource management strategies in *California Water Plan Update 2013* share a connection with sediment management. More information on each of these resource management strategies can be found in these chapters under Volume 3, *Resource Management Strategies, California Water Plan Update 2013.*

- "Agricultural Lands Stewardship," Chapter 21. Agricultural land stewardship directly links to management of erosion and soils protection. Proper management in both private and public land ownership prevents disruptive development patterns and supports sediment aware farming and ranching practices.
- Conveyance. Depending on design, conveyance facilities can either trap, scour, or result in other unnatural distribution of sediments. Sediment overload can significantly reduce system capacity.
- "Ecosystem Restoration," Chapter 22. Native riparian, aquatic, animal, and plant communities are dependent on effective sediment management. These ecosystems are dynamic and are highly productive biological communities given their proximity to water and the presence of fertile soils and nutrients. Many opportunities for improvement in both sediment management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains. Sediment management projects that result in protected and restored ecosystems will likely create increased effectiveness, sustainability, and public support.
- "Flood Management," Chapter 4. Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of the floodplain, the depth and composition of soils, and the type and density of vegetation. Sediment transport dynamics can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying capacity of natural channels through increased sedimentation. Sediment is also a major component of alluvial fan and debris-flow flooding.
- "Forest Management," Chapter 23. Forestation practices can influence sediment transport from upland streams. Wildfires can reduce surface water infiltration, which can cause additional erosion and debris flooding.

- "Land Use Planning and Management," Chapter 24. The way in which land is used — the type of land use, transportation, and level of use — has a direct relationship to sediment management. One of the most effective ways to reduce unnatural sediment loads is through land use planning that is fully abreast and reflective of applicable sediment and hydrology practices. This includes site design to reduce the introduction of unnatural loads of sediment into waterways.
- "Outreach and Engagement," Chapter 29. Outreach is needed to educate the public regularly on sediment management concerns. Outreach is also needed to educate the public on the natural beneficial functions of sediment.
- "Pollution Prevention," Chapter 18. Well-designed pollution prevention efforts improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion, and sedimentation of streams.
- "Municipal Recycled Water," Chapter 12. Soil structure can be altered by the composition of water that interacts with it, particularly sodium-loaded soil that may be found in many soils that have been irrigated with some recycled waters. Soil organic matter increases both the water-holding capacity of mineral soils considerably and the cation-exchange capacity. In soil science, cation-exchange capacity (CEC) is the number of positive charges that a soil can contain. It is usually described as the amount of equivalents necessary to fill the soil capacity. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. Some studies about infiltration rates between local well water (slightly calcic) and recycled water used for irrigation on a silty clay loam have found significant differences and reduced infiltration for the soils subject to the recycled water.
- "Urban Stormwater Runoff Management," Chapter 20. Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways and the timing and extent of sediment introduction into the system. The impervious surfaces increase runoff volumes and velocities, resulting in stream bank erosion and potential unnatural sediment distribution downstream. Watershed approaches to urban runoff management attempt to manage sediments to mitigate negative impacts and support beneficial uses in a manner that mimics the natural hydrologic cycle.
- Surface Storage. Similar to conveyance, sediments may be trapped behind infrastructure or otherwise unnaturally distributed. This results in a loss of system capacity.
- "Water and Culture," Chapter 30. Sediment is used in traditional ceremonies and considered to contain healing, and in some cultures, it has spiritual properties. Mud structures are important to native peoples and for some, mud has ties to the creation story. See *Tribal Water Stories* at http://www.waterplan.water.ca.gov/docs/tws/TribalWaterStories_FullBooklet_07-13-10.pdf.
- "Water-Dependent Recreation," Chapter 31. Water and land-based recreational activities can contribute to unnatural erosion and sediment production. Conversely, high sediment loads can negatively impact recreation, particularly boating, fishing, and swimming. Adequate supply of sand and gravel sediments is essential for many beach recreational activities.
- "Watershed Management," Chapter 27. Watersheds are an appropriate organizing unit for sediment management. Restoring, sustaining, and enhancing watershed functions are goals of sediment management in the context of integrated watershed management.

Potential Benefits

The ultimate benefits of sediment management relate to preventing the negative results of too little or too much sediment and repurposing sediment for beneficial uses. As noted above, benefits associated with reducing impacts just to navigation and commerce may achieve cost savings of millions. A similar statement can be made about the management of sediment that accumulates at reservoirs and debris basins and is prevented from flooding communities downstream.

Source Sediment Management

An average of 1.3 billion tons of soil per year are lost from agricultural lands in just the U.S. due to erosion (McCauley and Jones 2005) (http://landresources.montana.edu/SWM/PDF/Final_proof_SW3.pdf). Considering that soil formation rates are estimated to be only 10–25% of these erosion rates (Jenny 1980), loss and movement of soil by erosion is a major challenge for today's farmers and land managers. Soil erosion over decades can have detrimental effects on productivity and soil quality because the majority of soil nutrients and soil organic matter (SOM) are stored in the topsoil, which is the soil layer most affected by erosion. For these reasons and more, sediment management for soil sustainability has numerous multiple benefits far exceeding the scope of the California Water Plan.

In the case of urban land management, use of low-impact development and other sediment management practices can reduce negative impacts of stormwater runoff, by maintaining the natural production of sediment and improving permeability of drainage areas. Land use goals for sediment may also improve flood management. By improving the flood system hydrology, sediment management results in improved safety and environmental and economic outcomes.

Coastal Sediment Management

Sediment in the coastal waterways can furnish material needed to replenish the beaches and marshes along the coastal areas. If the sediment is removed from navigation channels or harbors, the extracted material can be used for beach or marsh nourishment, construction purposes such as highway sub-base material, and flood control levees.

Widening the shoreline, either via beach nourishment or marsh restoration, improves storm surge and flood protection. The dollar value of this improved protection is nearly incalculable, not just for those who own coastal structures, but for the extraordinary number of infrastructure improvements that support the state, including power generation, major transportation assets, water systems, and the dollar value of the recreation and tourism industries that are large part of the state's economy. Restoring eroded coastlines also improves habitat for coastal biota and improves access safety to the shorelines.

Fisheries

In terms of water management, natural amounts of coarse-grained sediment (sand and gravel) in the stream and river system has many beneficial uses. It can serve in the inland waterways as a substrate for fish spawning areas. Enhancing the sustainability of the fishery benefits not only the state's fishing industry, but is also a water supply benefit as a declining fishery may lead to reductions of water exports or use of some water rights.

Beneficial Uses for Extracted Sediment

Extracted sediment is a manageable, valuable soil resource with beneficial uses of such importance that it should be incorporated into project plans and goals at the project's inception to the maximum extent possible. For example, extracted sediment can benefit:

- Habitat restoration/enhancement (wetland, source, island, and aquatic sites including use by fish, wildlife, waterfowl, and other birds).
- Beach nourishment.
- Aquaculture.
- Parks and recreation (commercial and noncommercial).
- Agriculture, forestry, and horticulture.
- Strip mine reclamation and landfill cover for solid waste management.
- Shoreline stabilization and erosion control (fills, artificial reefs, submerged berms.).
- Construction and industrial use(including port development, airports, urban, and residential.
- Material transfer for fill, dikes, levees, parking lots, and roads.
- Multiple purposes (i.e., combinations of the above).
- Coastal Access.
- Storm Surge Protection.

The applicability of uses is subject to the demand for materials. An issue or barrier might be matching disposal to uses. A detailed discussion about various beneficial uses for extracted material is at http://water.epa.gov/type/oceb/ndt/beneficial_use.cfm and other related sources.

System Capacity and Materials Use

There are multiple benefits of managing the sediment that accumulates at reservoirs and debris basins. If sediment that accumulates in reservoirs is not removed, storage capacity is reduced. As an example, flood control reservoirs which have a water conservation purpose (and most of them do), water captured in the reservoirs maybe used to recharge local groundwater aquifers. If sediment is not removed or is passed through, then the storage capacity for water or hydropower is reduced. If sediment is not removed from reservoirs and debris basins, the ability to provide flood risk management, water supply, or hydropower is diminished.

Special Situations

The battle to maintain Lake Tahoe as a pristine and visual jewel is an unusual sediment case study. The sediment of concern is very fine-grained sediment (less than 20 microns) that affects the clarity and people's aesthetic enjoyment of Lake Tahoe. In this case, the problem may be unique and the extensive costs of basin-wide improvements would not translate to other situations. Even so, there have been many new and innovative best practices for sediment management in the basin and these can translate to other programs. Additionally the benefits of the investment have been equally evaluated and are considered to be of national interest.

Potential Costs

[PLACEHOLDER FROM WATER BOARDS - Include Lake Tahoe MS information on investments.]

Many agencies and organizations engage in sediment management activities. The cost of implementing sediment management to achieve water benefits varies widely depending on the sector and purpose of the management. When looking at the overall costs of sediment management, managers should consider and quantify the beneficial uses of the sediment and the ecosystem services, flood protection, storm surge protection, and water quality improvements associated with the benefits as a balance in comparison to the up-front financial investments. While the financial investment is often a one-time cost, the benefits are regularly long term, such as creating a wetland that provides habitat and water quality improvements in perpetuity.

A few sample investments in sediment management include:

Natural Resources Conservation Service (NRCS). From 2007 to 2012, the NRCS obligated more than $91 million in California for conservation practices to address soil erosion and sedimentation on agricultural land. These practices are recommended to reduce erosion, prevent the transport of sediment, or trap sediment before it leaves the farm or field.

USDA Forest Service. Overall, watershed restoration project costs on national forests are close to $2,000/acre, and most of these projects have the benefits of reducing erosion and sediment transport. Meadow restoration using the pond and plug approach is about $1,000/acre. Road decommissioning costs about $16/cubic yard of sediment (reduction in potential erosion).

Los Angeles County Flood Control District (LAFCD). Based on the alternatives included in the LACFCD’s Draft Sediment Management Strategic Plan (April 2012), the cost to manage the Strategic Plan’s 67.5-mcy planning quantity could be as much as $1.2 billion over the 20-year planning period, 2012 to 2032.

U.S. Bureau of Reclamation (USBR) and U.S. Bureau of Land Management (BLM). Gravels are added to Northern California rivers to aid in the anadromous salmon run each year. The amount of gravels added depends on the budget allocated each year. Such gravel additions are occurring in the upper Sacramento River area (i.e., Clear Creek), and in other rivers such as the American River, Yuba River, and Stanislaus River. The costs per ton of gravel added depends upon such factors as the method of placement, tonnage of gravel placed, and how the gravel is placed (e.g., dump trucks dumping gravel directly into river, lateral berms laid alongside the streambed at low water, or sluicing a mix of water and gravel directly into the river). Typical tonnages added may vary from 5,000 to 10,000 tons and more per application. Also, the U.S. National Fisheries Service specifies the amount of cleaning (washing) that has to be done to the gravels prior to application, and the grain size distribution of the gravels, which adds to the cost.

Major Implementation Issues

The issues for implementing sediment management are similar to those experienced by related resource management strategies including:

- The need to balance environmental impacts, social impacts, feasibility, and cost.
- Availability and affordability of land.
- Different stakeholders have different needs and different understandings of the need to manage sediment.

- Local managers implementing site-specific solutions without consideration of the regional backdrop and how regional processes affect the local conditions.
- Stakeholders and regulators lack a complete understanding of the different natural regional sediment regimes and attempt to address issues on a statewide basis.
- Urbanization and other structural limitations may preclude introduction of natural regimes.
- Supply/demand regarding extracted sediment in terms of quantity and timing, sediment type, and use. Beneficial use is contingent or recipients for managed sediment.
- Conflicting federal, State, and local regulations, agency missions, and regulators' unwillingness to compromise navigate these conflicts for the good of a region.
- Significant resistance by some local interests concerned with siting and transfer of impacts. Lack of advocacy to counter negative attitudes, e.g., "don't see, don't care."
- Budget constraints, including the need to find funding source to pay for the incremental costs of RSM.

Sustainability issues facing the three management approaches — sediment source management, sediment transport management, and sediment disposition management — follow.

Sediment Source Management

Lack of Techniques for Coarse-Grained Sediments Management

There is a desire for the coarse-grained fraction of the natural supply of sediments (sand and gravel), but not the fine-grained sediments (silts and clays) from the watershed to enter the streams and rivers so they can replenish these sediments in fish spawning areas, and also move toward the ocean thereby replenishing the sand along the coastal beaches. Research is needed in this area because not many techniques currently exist for coarse-sediment bypassing in inland watersheds. One project in the Bay Area, Flood Control 2.0, recently funded by the EPA Water Quality Improvement grant program, is examining this question. The project will be underway during the next four years and will examine the coarse-grain load in Bay Area flood channels, characterize the channel configurations and constraints, and then identify ways to move coarse-grain sediment through the channels to the shoreline or to develop bypass areas where the sediment is diverted into habitat areas where it is much needed.

In particular, efforts must be made to keep coarse-grained sediments available and clean in fish spawning rivers and streams. Erosion in unstable watersheds brings fine-grained sediments into the channels which may settle and cover the coarse-grained sediments needed for spawning, thus eliminating them from use in the spawning process. This web site, published by Joseph M. Wheaton, describes these needs: http://www.joewheaton.org/Home/research/projects-1/past-projects/spawning-habitat-integrated-rehabilitation-approach-shira-.

Barriers to Supplying Coarse-Grained Sediments to the Coastal Beaches

Many of the beaches along the coastline are receding because their natural supply of coarse-grained sediments from inland rivers has been stopped by dams, extracted for use, deposited on impermeable pavements, coastal armoring, in-stream sand and gravel mining, stormwater controls, changes to the ground surface, and other land use practices.

Instream sand and gravel mining removes a resource that downstream environments need. This situation is anticipated to become worse and accelerate with sea level rise. As noted above, the CSMW is working toward this effort, but challenges remain as agencies aim to work collaboratively, identify the necessary funding, and overcome the traditional jurisdictional conflicts that create misalignment of policy and regulation. Current Corps policy for placement of dredge materials is the lowest-cost alternative which is not always where it could be used best. Sediments can also be used to restore the template of flood protection and in some cases, operations can be moved out of the stream or a mitigation fee can be imposed.

Along the coast, beach nourishment has usually been undertaken by combining the USACE's or other dredgers' maintenance dredging of sandy areas and pumping it or placing adjacent to or directly on the shoreline for distribution either via wave action or by mechanical means. This practice has been well received, however funding remains minimal. Even with these successes, a challenge to beach replenishment occurs when material must be transported over land through beach neighborhoods in order to get to the beaches. In some California locations, sandy beaches, primarily used for recreation, are human-made and require continual replenishment, maintenance, and support.

Cost Allocation

The issue of whose budget pays is a major barrier to reuse of any kind. Often reuse is not only environmentally beneficial, but also presents the optimal use of society's funds. Even then, if the dredging budget will not pay for any increase in placement costs compared to disposal, and if the reuse site will not share some of the costs for receiving otherwise free material from the dredging project, the reuse does not occur. A USACE publication addresses this problem, which is available at http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/upload/2009_02_27_oceans_ndt_publications_2007_fed_standard.pdf.

Additionally, current USACE policy for placement of dredged material requires the lowest cost alternative which typically means transport to the location (e.g., beach) closest to the dredge area. Lack of broader policy discussion of this general issue is a lost opportunity to recommend to the Legislature to do a number of things. For example, the Legislature should encourage congressional action to revise how the Harbor Maintenance Trust Fund is distributed and to continue support or even increase funding to entities such as the Coastal Conservancy to share costs with USACE for dredging projects. Cost-benefit ratio for dredge disposal incremental (NED).

Controlling Excessive Sediment from Entering Eutrophic Waterways

Eutrophic waterways typically have a lot of minerals and organic nutrients that are used by plants and algae. They often appear dark and have poor water quality. This occurs when certain nutrients, such as phosphorus, are absorbed on fine-grained sediments and carried into the waterways and lakes. These nutrients can cause algal blooms to be out of control in a lake which then creates a lack of oxygen resulting in fish kills. The sediments also result in a reduction of light and clarity in lakes, thereby harming the food chain and also reducing the aesthetic quality of the lake. Controlling these conditions is challenging and failing to do so is especially harmful to Lake Tahoe.

Implementation of Regional Sediment Management

There are obstacles to the practical implementation of RSM. RSM requires a long-term, multi-year watershed view for planning. Yet, it may be difficult for stakeholders and regulatory agencies to adopt long-term views and without the necessary scale. Federal, State, and local regulations are sometimes in conflict with each other. Successful RSM requires compromises from everyone. Regulators often do not offer a compromise due to statutory requirements, not recognizing others' jurisdiction, and fear of exposure to third party lawsuits. Additional challenges for RSM are finding re-use projects/activities that occur at the same time that the sediment needs to be removed, long distances between potential users and the sediment source, and opposition from inhabitants/stakeholders. CSMEs Costal RSM Plan program aims to address many of these issues by providing a cogent, strategic methodology to address sediment imbalance issues within the specified region using RSM.

Limited Options Due to Other System Requirements

In some cases, the optimum sediment management approach may be precluded due to other system requirements or previously implemented decisions and goals.

As an example, a major shift in land use and population patterns may not be feasible. On a specific project level, large amounts of sediment already accumulated behind reservoirs prohibit the immediate implementation of a different approach to sediment management (e.g., a reservoir may need to be cleaned out to its original condition before a sediment flow-through approach can be implemented).

Also important is the instream sand and gravel mining industry, which, according to some authors (e.g., Magoon) may represent the largest source of downstream loss, but is also providing important benefits to the local economy and source materials for multiple critical uses.

Sediment Transport Management

The discipline of sediment transport management is emerging. Much remains to be learned about the best ways to manage for instream sediment quality objectives to prevent aquatic organisms from being smothered by sediment while also providing sediment for downstream processes and needs.

Lack of Monitoring on Stable (Reference) Sediment Conditions in Watersheds

Altered channels have changed natural hydrogeomorphology and natural sediment processes. There is a benefit in achieving and maintaining watersheds in a stable condition as it relates to the generation and transport of sediments from the land surface to the surface streams. This requires understanding (assisted by geomorphic assessments on channels) and monitoring to determine when watersheds are stable or unstable. Management without these tools causes stream channels to degrade in their geomorphic form and they will not support the native aquatic biological habitat. This affects domestic water supplies (filtration). Unstable sediment conditions may also result in disruption of flood control structures.

Achieving Broad Support for Establishing and Implementing Biological Objectives in Streams

The State Water Resources Control Board is establishing biological objectives, which will include those for suspended sediment as well as deposited sediments (see http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml). Excessive sediment in streams, as well as lack of natural sediment loads, can be detrimental to the aquatic life. Achieving broad support for establishing and implementing biological objectives is sometimes met with resistance.

Sediment Deposition Management

Sediment impacts through turbidity, dredging, or burial are also of concern in the coastal environment. Dredging has the potential to destroy habitat and biota currently residing in that habitat, while placement of sands has the potential to bury biota at the placement area or downcast from it. Both of these activities have the potential to create turbid conditions that if are not abutted, could create adverse conditions for filter feeders, visual predators, and photosynthesis. The CSMW's Biological Impacts Analysis and Resource Protection Guidelines discusses these potential impacts in detail, as well as recommending methodologies to minimize such impacts.

Securing Disposal/Placement Locations

Finding disposal locations has become increasingly difficult and expensive due to development of nearby land, regulatory constraints/requirements, or opposition from those adjacent or along the haul routes to the deposition sites.

Another challenge to disposing of/reusing dredged sediment on dry land is dewatering the sediment. Due to the high content of water if the project is hydraulically dredged, the dewatering areas need to be quite large and a region may not have sufficient space available.

When dredged material is placed at an upland dewatering or stockpile site, often future beneficial uses are not known until a particular reuse is proposed and the Regional Water Quality Control Boards analyze the sediment quality data that was collected during dredging. This is because sediment that may be chemically suitable (considered to be “clean enough”) for one kind of reuse may not be suitable for other kinds of reuse. Often this results in delays for projects wanting to reuse the sediment, and can also constrain the emptying and use of the storage sites for future projects.

Handling Contaminated Sediments

Management of contaminated sediments may be challenging. There are limited resources for cleaning of the sediments and disposal of containments taken from contaminated sediments. The USACE has a National Center of Expertise for handing contaminated sediments at http://el.erdc.usace.army.mil/dots/ccs/ccs.html.

Contaminated Sediment Management

The potential for contamination is a consideration whenever dealing with sediments, whether these are in upper watersheds or in ports and harbors. When a project or a watershed has to contend with contaminated sediment, special considerations need to be applied. Even contaminated sediment can often be reused, but a more limited set of potential uses for that sediment may be available.

Reuse Challenges

Appropriate reuse is sometimes cost-prohibitive. Challenges to using sediment for beneficial uses include finding beneficial use projects that coincide with the timing of sediment removal, long distances between the sediment removal site and the beneficial use site, offloading equipment needs, encountering regulatory obstacles, and encountering steep disposal fees at the beneficial use site.

Regulatory Requirements

Regulatory and management frameworks involving sediment typically are designed to support specific uses. As a result, they involve multiple agencies and jurisdictions that are not necessarily accommodating of the complexities of managing all the aspects of sediment sources, transport, and deposition. As a result, sediment-related projects and/or multiple benefit projects may not be feasible due to timing, costs, and conflicts related to the desired deposition of the sediment. Regionally, the LTMS program previously described provides a cooperative framework for testing, permitting, and beneficial reuse projects. The LA-CSTF is a similar interagency regulatory group. Significant effort and energy is required to maintain such cooperative and collaborative efforts when dealing with dredging and beneficial reuse projects. CSMW also functions as a clearinghouse for member agencies to identify sediment-related activities of interest to other agencies.

Data Availability

A number of issues related to integrated management and better planning and coordination could be improved with better data availability. For example:

- Better planning and decision-making could occur with coordinated mapping efforts to allow agencies to better consider upstream and downstream impacts prior to decision-making.
- Ongoing monitoring would allow better adaptive management and an evaluation of management methods being used.
- Improved forecasting and modeling would support long-term and strategic planning.
- Development of sand and sediment budgets would assist agencies in planning and reduce regulatory conflicts.

Data challenges can be addressed. For example, CSMW maintains a Web site designed to make as much information as possible to costal sediment managers. In addition, there are many Web sites that are devoted to specific topics that CSME has been involved with since 2003. These range from a topical library containing links to relevant reports to a searchable database of references. A spatial database containing numerous data layers is at http://www.dbw.ca.gov/CSMW/default.aspx.

Sediment and Climate Change

Climate change is already occurring and it is projected to continue to alter temperature and hydrology patterns in the state. Climate change studies project an increased frequency of extreme weather, higher temperatures, larger and more frequent wildfires, longer droughts, and more precipitation falling in the form of rain than snow. These changes will bring shifts in vegetative species, heighten soil exposure, and will cause flooding to already vulnerable lands and coastlines, adding a heavy mix of sediment and debris to stormwaters. Coupled with sea level rise and surge, which increases coastal erosion (e.g., more than just beach erosion, and coastal flooding, climate change will amplify the already difficult task of sediment management. Drought and climate change alter permeability and other physical characteristics of sediment. Increased carbon dioxide levels may influence soil chemistry.

Adaptation

Adaptation will necessitate projecting where excessive sediments will source and accumulate, and it is also necessary to build controls that will allow for effective management of those sediments. With climate change expected to bring wetter winter and drier summers, erosion will become an even greater threat to California lands and sediment management. Several adaptation strategies may provide benefits in light of climate change.

In some places, floodplain restoration is feasible. This tactic allows for natural deposits of beneficial sediment and serves dual purposes of managing sediment and replenishing soil. Excess, clean sediment can be used beneficially on eroding beaches and agricultural lands, augmenting natural processes. The Coastal Commission is also funding pilot projects for growing wetlands to protect against surge.

Managed retreat is also a tactic that can be used to manage impacts associated with changing beach width caused by climate change.

Warmer temperatures and higher levels of CO_2 may, in some cases, lead to increased vegetation. Vegetation can minimize runoff and lessen erosion, preventing sediments from entering waterways. Effective management of landscapes including planting heat- and drought-tolerant native vegetation around waterways will minimize sediment loads.

Mitigation

Sediment management is a continuous process that can result in high greenhouse gas (GHG) emissions. Dredging and channel clearing is necessary to ensure adequate capacity for flood protection, water supply, and navigation, but is a constant source of GHG emissions from fossil fuel-powered equipment. Ports in some areas have begun to convert to shoreside electric power that could be sourced to renewable energy as more dredges use electric power, but this will take a major industry effort to convert to a different system. Additional analysis should be undertaken to fully recognize the value of beneficially reusing dredged sediment in habitat projects, and the carbon sequestration capabilities of marshes and riparian habitats. Once these analyses are completed, projects can evaluate whether the GHG created by dredging are fully offset by the beneficial use project.

Recommendations to Facilitate Sediment Management

New recommendations for sediment management may increase costs and/or the amount of time needed to obtain permits. All new sediment recommendations should be strongly evaluated to determine to what extent they could inhibit important water/flood projects and activities. If impacts may occur, some form of mitigation for these effects should be included when implementing any given recommendation.

Policy and Regulatory Reconciliation

1. The State and USACE should convene a stakeholder working group that includes flood protection and water supply entities to recommend methods to overcome sediment management regulatory conflict and encourage long-term thinking, including the issuing of permits that match the time horizon for any established sediment management plan. The stakeholder working group should consult and build upon the successes of the CSMW, because they have tackled many of the issues in a coastal setting that will be encountered by those seeking to implement RSM in inland areas.

2. The USACE, Natural Resources Agency, California Environmental Protection Agency, Department of Finance, Governor's Office of Planning and Research, and the California Water Commission should convene a task force or stakeholder working group to recommend methods for sediment management cost allocation. Often reuse is not only environmentally beneficial, but also presents the optimal use of funds.
   A. The stakeholder group should also evaluate needs for outreach and education on sediment management and offer recommendations for next steps to address those needs.
   B. Specific focus should be given to cover the incremental costs of RSM.

Sediment Source Management

3. The Governor's Office of Planning and Research should develop model general plan guidelines that support optimum sediment source management.
4. Federal, tribal, State, regional and local agencies and stakeholders should support and participate in Regional Sediment Management for those sediments which must be dredged to keep the waterways and other facilities open to navigation or to support flood control efforts. Also, there should be support of those efforts to use that sediment beneficially within regions. One possible use of the sediment is levee construction that can direct the floodwater to the most desirable location.
5. The State Lands Commission and other responsible agencies should scrutinize instream and beach Sediment Mining Permits. The Commission should evaluate impacts of sediment-mining permits on a case-by-case basis, which allow the removal of coarse-grained material directly from stream beds or from coastal beaches. While such permits may be satisfactory in some instances, in other instances such permits reduce the sediment needed for fish spawning beds and for beach replenishment.
6. The State should implement the requirements recommended by the California Association of Storm Water Quality Agencies (CASQA) for stormwater discharge control programs associated with sediment management which
   A. Are technically and economically feasible.
   B. Provide significant environmental benefits and protect the water resources.
   C. Promote the advancement of stormwater management technology.
   D. Are compliant with State and federal laws, regulations, and policies. Reducing or controlling stormwater discharges keeps watershed and industrial pollutants from running into the waterways, thereby improving water quality.
7. The Regional Water Quality Control Boards should work with stakeholders to secure broader support of sediment water quality requirement efforts and promote development of stakeholder-based implementation plans to address excessive sediment problems.

Sediment Transport Management

8. The State should support research and design of fine-grained and coarse-grained sediment bypass structures. This will allow the coarse-grained sediment to be separated and either enter the streams and serve its many beneficial uses there, such as for fish spawning grounds and the restoration of coastal beaches, or be trapped in detention ponds where it can be excavated and used beneficially. The fine-grained sediment will be separated and can be used for wetland establishment or other uses. The separation and removal of fine-grained sediment with their attached nutrients can help improve the water quality in lakes having excessive eutrophication.

This work will need to account for water quality requirements and other interests, such as fishing and recreation.

9. The State should encourage the use of remote sensing as a tool for sediment transport management.
10. The State should support the use of watershed mathematical models, when the occasion demands, which can track sediment from source to transport in the streams. Such models (such as SWAT, HEC-HMS, and HSPF) need adequate calibration and validation, but once calibration is done, these models can help to manage the sediments throughout the watershed. The watershed model can also predict the concentrations of other water quality substances in the water.
11. The Natural Resources Agency and California Environmental Protection Agency should implement, as much as possible, an integrated approach to achieve the maintenance of stable watersheds. A stable watershed is one where sediment yield mimics the natural sediment production that would occur in the absence of anthropogenic conditions. If the watershed is not stable, assist in efforts to make it so.

Sediment Deposition Management

12. Where feasible, the State in cooperation with the local sediment management agencies should determine the Sediment Yields of Watersheds when downstream sediment problems are becoming an issue. This type of monitoring may not be feasible in undeveloped, highly-erosive mountain areas. These yields (such as in tons/square mile/year) can be determined at monitoring sites, which have matching pairs of suspended sediment concentrations and instantaneous flow rate measurements. Knowing the sediment yields will help to manage extraction and dredging budgets for the navigation channels and other non-navigation facilities.
13. The Regional Water Quality Control Boards in cooperation with the local sediment management agencies should expand use of regionally-based sediment screening criteria so that agencies could know sooner what the use of the dredged material could be and plan accordingly. Establish potential uses of dredged material, depending upon its quality, in advance. The upland sites receiving dredged material can then be emptied sooner and become available for additional dredged material. This will assist in maintaining the shipping channel in operational condition.
14. The State Lands Commission and DWR should prepare sand budgets for each watershed when downstream sand availability issues are occurring. Comparisons of these sand budgets over time for each watershed will tell of the effect of source Best Management Practices in affecting sand transport, will be of use in determining how well sand is moving toward the coastal beaches, will allow comparison of sand generation in the watershed to that removed by in-stream sand removal permits, and will tell which watersheds are the best in generating sand. These sand budgets should include the sand budgets developed for coastal areas, including the regional sediment budget studies conducted by UCSC for CSMW.
15. All affected jurisdictions should work with or through the CSMW, because it is preparing coastal RSM plans for most of the littoral cells along the coast.
16. The State should support and provide incentives for expanding successful interagency models to cover dredging projects throughout the state. Identifying beneficial reuse opportunities that support RSM goals should be a key objective of the State's involvement.
17. The State should develop a funding source to encourage and support beneficial reuse projects, specifically those that enhance, restore, or support habitat including beach nourishment and

wetland restoration projects. State funding can be partnered with federal and private funds to support these efforts.

18. The State may also consider ways to encourage beneficial reuse of sediment without State funding. Specific ideas include providing a tax credit or mitigation credit when sediment is reused beneficially rather than treated as a waste product.
19. The State should enable funding for special districts and local governments to undertake sediment management actions. This could include the ability to levy taxes for sediment management, similar to infrastructure districts.
20. For sediment removal projects from facilities that capture sediment from undeveloped watersheds (e.g., some dams and debris basins), State agencies should allow pre-testing to facilitate deposition of sediment at solid waste landfills, inert landfills, and other potential deposition sites, which otherwise may require testing and affect beneficial use of sediment, especially in emergency situations.

Data Acquisition and Management

21. Federal and State governments should support development of guidelines to identify when geomorphic assessments of streams for watershed stability are appropriate to prevent undue delays in processing permits and ensure that studies are scaled to project size.
22. The Federal and State governments should support sediment and flow monitoring programs of others if needed to determine the sediment yields from a watershed and sediment budgets for downstream areas. They should also establish monitoring protocols that produce scientifically-defendable data of comparable quality throughout the state. Such monitoring will add to the water quality data base of the waterway.
23. The Federal and State governments should support modeling and monitoring for sediment dynamics in estuarine and near-shore (littoral cell) environments when understanding estuarine and near-shore sediment transport issues is key to adaptive management, infrastructure protection, and habitat restoration.
24. The State should expand efforts for a sediment data exchange and cooperate with others who may be obtaining sediment data in a watershed so that a common database is used that is accessible to all users. Stakeholders should be convened to establish data needs and requirements. CSMW has developed a GIS database and associated web viewer, and is working with the Ocean Protection Council to incorporate their spatial data into the State Geoportal, currently under development. The State Geoportal is envisioned as a one-stop location for most of California agencies' geospatial database.
25. All responsible agencies should utilize a common GIS mapping framework and use GIS to overlay maps relating sources of excessive sediment production in watersheds with areas having sediment problems in the stream in those watersheds.

PLACEHOLDER Box 26-3 Case Study: Sediment Management Related to Recreational Use

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-6 Case Study: Clear Lake — Algae in Clear Lake

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

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Table 26-1 Agency Roles and Activities in Sediment Management

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Federal	US Department of Agriculture (USDA) Forest Service Natural Resources Conservation Service) Dept. of Interior (DOI) Bureau of Land Management US Geological Survey Park Service Defense USACE	Land Managers, Advisors	Support California land management practices that incorporate erosion control and sediment management. Landscape Conservation Cooperatives
Federal	Dept. of Interior (DOI) US Fish and Wildlife Service Dept. of Commerce NOAA US EPA USACE	Regulators Advisors	Oversight for Dredging, fisheries and TMDL issues
Tribal	Tribal Governments	Land Managers, Planners	Plan and manage for sediment management considerations.
State	CalFIRE Board of Forestry and Fire Protection (BOF) State Lands Commission State Parks Fish & Wildlife	Land Managers Advisors Planners Regulators	Promotion of sediment management through best forest management practices. For over 20 years a group of advisors called the Monitoring Study Group (MSG) has, and continues, to: (1) develop a long-term program testing the effectiveness of California's Forest Practice Rules, and (2) provide guidance and oversight to the California Department of Forestry and Fire Protection (CAL FIRE) in implementing the program. The MSG has sponsored significant research on sediment management. This research informs CAL FIRE funded monitoring efforts designed to ascertain if forest practice rules, reducing unnatural sediment loads and protecting beneficial uses of water are being implemented and are effective.
State	Department of Food and Agriculture Department of Conservation Fish and Wildlife The University of California Extension Farm Advisors	Advisors Grant Administrators Training & technical Assistance	Provide significant leadership in source sediment management through the development of Best Management Practices (BMPs)

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
State	Water Boards	Regulators Training & technical Assistance	Protect water quality through the issuance of regulations and permits which also serve as National Pollutant Discharge Elimination System (NPDES) permits for point source discharges subject to the Clean Water Act. Permits related to sediment control include stormwater permits for municipal stormwater systems, highways and other thoroughfares and construction activities. Permits require the implementation of best management practices (BMPs) at constructions sites, outreach and education to residents, and consideration of the principles of low impact development for redevelopment and new development sites. Non-point source (NPS) pollution can include sediment or pollutants carried by sediment. NPS pollution is divided into the following six categories: (1) agriculture; (2) forestry; (3) urban areas; (4) marinas and recreational boating; (5) hydromodification activities; and (6) wetlands, riparian areas, and vegetated treatment systems. The Water Boards administers grant funding to develop and implement management practices to address NPS pollution such as development and implementation of the California Rangeland Water Quality Management Plan (http://www.waterboards.ca.gov/publications_forms/publications/general/docs/ca_rangeland_wqmgmt_plan_july1995.pdf).
Regional	Sierra Nevada Conservancy	Planning Financial Assistance Training & technical Assistance	Promotion of land use practices that support optimum source sediment management
Regional	Tahoe Regional Planning Agency	Planning Regulation	Promotion of land use practices that support optimum source sediment management
Local	Local Governments, Districts, Water Agencies, Reclamation Districts and Planning Commissions	Planning Regulation	Promotion of land use practices that support optimum source sediment management. Some local governments (city and county) support Low Impact Development (LID), including it as part of their planning and development ordinances. LID features design elements, including hydromodification, that address sedimentation at the source. Resources, including model regulations, are available to help municipalities interested in incorporating sediment source management into their planning portfolios. Local governments may also be involved in flood protection and water supply. (http://www.epa.gov/owow/NPS/lidnatl.pdf, http://www.epa.gov/region1/topics/water/lid.html, http://efc.muskie.usm.maine.edu/docs/lid_fact_sheet.pdf, and http://www.huduser.org/publications/pdf/practlowimpctdevel.pdf & http://www.mass.gov/envir/smart_growth_toolkit/bylaws/LID-Bylaw-reg.pdf).

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Local	Cities Counties JPA's Commission's	Advisors	Develop a land stewardship ethic that promotes long-term sustainability of the state's rich and diverse natural resource heritage.
Local	Resource Conservation Districts	Planning, technical and financial assistance	Resource Conservation Districts (RCDs) implement projects improving sediment management on public and private lands and educate landowners and the public about resource conservation. They work together to conduct: • Watershed planning and management. • Water conservation. • Water quality protection and enhancement. • Agricultural land conservation. • Soil and water management on non-agricultural lands. • Wildlife habitat enhancement. • Wetland conservation. • Recreational land restoration. • Irrigation management. • Conservation education. • Forest stewardship. • Urban resource conservation.
NGO	California and local Farm Bureaus California Rangeland Trust TNC	Advisors Advocates Training & technical Assistance	Information development and dissemination, policy advocacy Land Holding Services
NGO	California Association of Storm Water Quality Agencies (CASQA)	Advisors Advocacy Training & technical Assistance	Assists the Water Boards and municipalities throughout the state of California in implementing the National Pollutant Discharge Elimination System (NPDES) stormwater permits. One of the accomplishments of CASQA has been the development and dissemination of Best Management Practices (BMP) Handbooks. The BMPs help reduce unwanted delivery of sediment. The handbooks are designed to provide guidance to the stormwater community in California regarding BMPs for a number of activities affecting water quality and sediment management, including New Development and Redevelopment, Construction Activities, Industrial and Commercial Activities, and Municipal Activities (CASQA Web sites: http://www.casqa.org/ and http://www.cabmphandbooks.com).

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Private Interests and Land Managers	PG&E, Southern California Edison and other major private utilities with large land and water holdings and infrastructure. Tejon Ranch. Irvine Ranch, etc. Timber & Rail companies (e.g. Sierra Pacific, Catellus Corporation, a successor to the Southern Pacific Land Company and affiliated with Santa Fe Pacific) Agriculture	Land Management	Pacific Forest and Watershed Lands Stewardship Council (PG&E) Irvine Ranch Conservancy Tejon Ranch Conservation and Land Use Agreement

Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

[photo to come]

Box 26-1 Debris and Sediment

The Sediment Resource Management Strategy (RMS) relates to organic materials. However sediment and debris are often comingles.

Approximately 80 percent of marine debris in the world's oceans originates from land-based sources- primarily trash and debris in stormwater and urban runoff. Studies have found that significant quantities of small plastic debris originating in urbanized land areas pollute the Pacific Ocean both near-shore and on beaches and segments of the ocean thousands of miles away from human habitation.

Studies of debris in Southern California coastal waters demonstrate that significant quantities of trash and debris originate from urban areas and are comprised of pre-production plastics from plastic industrial facilities, trash and litter from urban areas, and boating and fishing-related debris.

More about this topic may be found in the Pollution Prevention and Stormwater-Urban Run Off RMS chapters.

Source: California Coastal Commission and Algalita Marine Research Foundation, n.d.

Box 26-2 Definitions

Suspended load is the portion of the sediment that is carried by a fluid flow which settles slowly enough such that it almost never touches the bed. It is maintained in suspension by the turbulence in the flowing water and consists of particles generally of the fine sand, silt and clay size.

Bed load describes particles in a flowing fluid (usually water) that are transported along the bed of a waterway.

Wash load is the portion of sediment that is carried by a fluid flow, usually in a river, such that it always remains close the free surface (near the top of the flow in a river). It is in near-permanent suspension and is transported without deposition, essentially passing straight through the stream. The composition of wash load is distinct because it is almost entirely made up of grains that are only found in small quantities in the bed. Wash load grains tend to be very small (mostly clays & silts but some fine sands) and therefore have a small settling velocity, being kept in suspension by the flow turbulence.

Box 26-3 Case Study: Sediment Management Related to Recreational Use

Off-highway vehicle (OHV) use is a popular form of recreation in California. State and federal agencies provide recreational areas for this purpose. These OHV recreation areas need to implement a range of storm water best management practices to protect water quality. Additionally, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted storm water. With limited resources, maintaining and policing these areas can be a challenge.

In 2009, the Central Valley Water Board found that portions of the Rubicon Trail located in El Dorado County were severely eroded, erosion was accelerated by OHV use and sediment was being discharged to surface waters. (see following 3 photos provided courtesy Monte Hendricks) To address this problem as well as other OHV related water quality issues, the Central Valley Water Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2009) to El Dorado County and Eldorado National Forest to develop and implement plans to improve management of the trail and protect water quality.

PLACEHOLDER Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

PLACEHOLDER Photo B [title to come]

The Rubicon Trail Foundation, in response to critisms over OHV use of the Rubicon Trail, has been involved in restoration activities and, in testimony to the Central Valley Water Board, provided some photos of improvements. The following three photos (also see pdf of the actual slides from the testimony to the Central Valley Water Board) show before, during and after photos of an eroded site.

In 2012, the Central Valley Water Board found that sediment disturbed by recreational vehicle activity and transported in storm water runoff to Corral Hollow Creek was a water quality problem at the Carnegie State Vehicle Recreation Area. The Board also identified metals, such as copper and lead, as a potential concern. To address these problems, the Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2012) to the California Department of Parks and Recreation (State Parks). The Order recognized that State Parks had developed a Storm Water Management Plan that describes the best management practices that need to be implemented to address erosion and sedimentation. The Order required State Parks to and implement the Storm Water Management Plan update.

PLACEHOLDER Photo C Off-Highway Vehicle — Sediment Settling Pond

— Betty Yee, Central Valley Regional Water Quality Board

Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

[photo to come]

Photo B

[title and photo to come]

Photo C Off-Highway Vehicle — Sediment Settling Pond

[photo to come]

Box 26-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

In the 1800s and early 1900s, the Los Angeles Region experienced catastrophic floods that resulted in loss of life and property. Consequently, in 1915, the California State Legislature adopted the Los Angeles County Flood Control Act. The Act established the Los Angeles County Flood Control District and empowered it to provide flood risk management and conserve flood and storm waters. The Flood Control District encompasses most of Los Angeles County, including the highly erosive San Gabriel Mountains as well as other mountain ranges. The Flood Control District operates and maintains 14 dams and reservoirs, 162 debris basins, 500 miles of open channel, and other infrastructure.

Given the region's highly erosive mountains and the existing system, managing flood risk and conserving water goes hand in hand with removing and managing the sediment that accumulates at the facilities. Sediment is delivered to the facilities as a result of runoff in the mountains picking up and carrying material eroded from the mountains. The amount of sediment that reaches a facility any given year depends on the size of the watershed, the watershed's vulnerability to erosion, watershed conditions (such as vegetated watershed versus burned watershed), and weather conditions (such as amount and intensity of rain).

Wildfires greatly increase the amount of runoff and erosion from mountainous watersheds. As much as 120,000 cubic yards of sediment and debris have been produced per square mile of a burned watershed after a major storm. The first four years after a fire have proven to be the most critical in terms of the potential for increased delivery of sediment and debris to the Flood Control District's facilities. The effects of wildfires were taken into consideration during the design of the dams under the jurisdiction of the Flood Control District and continue to be considered for today's operations.

The Station Fire of 2009 was the largest fire in Los Angeles County's recorded history, burning approximately 250 square miles. The fire started on August 26th and was not fully contained until October 16th. The burned watersheds resulted in a significant increase in the amount of sediment and debris eroding from the hillsides during storms and making its way into debris basins and reservoirs. After a short but powerful burst of rain in mid-November 2009, Mullally Debris Basin, which is located in the City of La Cañada-Flintridge and has a 9,400- cubic-yard capacity, filled up in 30 minutes. There were also storms in January and February 2010 that delivered tremendous amounts of sediment to the facilities. The images shown below illustrate the amount of sediment that reached Dunsmuir and Mullally Debris Basins as a result of the Station Fire and the storms of February 2010.

PLACEHOLDER Photos A-D Dunsmuir and Mullally Debris Basins

Immediately following the Station Fire and the 2009-2010 Storm Season, a total of approximately 1.2 million cubic yards (MCY) of sediment were removed from 38 debris basins in order to reduce flood risk for the communities downstream of those debris basins from subsequent storms that still had the potential to send overtopping flows into the debris basins. In addition, many k-rails were installed in the streets of the foothill communities to direct flows away from houses in the event of debris flows due to overtopped debris basins. Emergency operations involved day and night work and trucking of sediment through neighborhoods. The total amount of sediment removed that year is the largest amount removed in any year since the Flood Control District began managing sediment accumulation in debris basins in the 1930s. Notably, the amount of sediment inflow to debris basins is small compared to the amount of sediment that impacts the reservoirs the Flood Control District maintains.

The Station Fire burned significant portions of the watersheds of four reservoirs, as listed below.

- Big Tujunga Reservoir: 88 percent of the reservoir's watershed.
- Cogswell Reservoir: 86 percent of the reservoir's watershed.
- Devil's Gate Reservoir: 68 percent of the reservoir's entire watershed, 92 percent of the reservoir's undeveloped watershed.
- Pacoima Reservoir: 80 percent of the reservoir's watershed.

Based on the Flood Control District's records, 3 of the 4 reservoirs have had an additional 1 MCY of sediment accumulate in them, as detailed in the table below. The potential for high sediment inflows into both reservoirs and debris basins will continue until the watersheds recover.

Table A [title to come]

Reservoir	Date of last survey prior to or soon after Station Fire	Date of last survey [a]	Amount accumulated between subject surveys	Challenges
Big Tujunga	October 2009	August 2011	1.6 MCY	1,2,3,5
Cogswell	December 2009	August 2011	1.7 MCY	1,2,3,5
Devil's Gate	April 2009	March 2011	1.2 MCY	4,5
Pacoima	January 2009	September 2011	0.4 MCY	1,3,4,5

[a] As of June 2012

1 – Limited access ; 2 – Limited space at adjacent or nearby sediment placement sites; 3- Endangered species present downstream; 4- Conflicting environmental interests; 5- Long haul routes to facilities with available space

Another consideration at reservoirs is the amount of sediment already accumulated in them** and the capacity available for additional sediment accumulation that would not interfere with the dam's operations. Given the current volume of sediment and the high potential for large sediment inflows, the Flood Control District is planning sediment removal projects at the four reservoirs affected by the Station Fire. These projects are currently estimated to remove a total of 14 MCY of sediment over the next 8 years, with each project lasting 3 to 5 years and costing as much as $50 million.

** Significant amounts of sediment had accumulated in the subject reservoirs prior to the Station Fire (the same is true of other reservoirs operated and maintained by the Flood Control District). This is the result of a combination of issues, including the following:

- Diverse stakeholder interests, which result in different opinions on the "best" sediment removal, transportation, and placement alternative that should be used for a project.
- Conflicting regulatory requirements.
- Restrictions from other agencies.
- Costs.

— Greg Jaquez, LA Flood Control District

Photos A-D Dunsmuir and Mullally Debris Basins

[photos to come]

Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

Following is story about a proposal to remove a dam (http://www.sandandgravel.com/news/article.asp?v1=13621). While the San Clemente Dam no longer is providing the water supply function it was intended to meet, that may not be true for other dams in the State. For example, LA County has a lot of people (most of its 10 million population) depending on LACFCD's and Corps' dams for flood protection & water supply. This makes a discussion of sediment and dam removal essential to the water management discussion.

News - September 27, 2010

California American Water has filed an application with the California Public Utilities Commission requesting permission to remove the San Clemente Dam on the Carmel River in order to resolve seismic safety concerns associated with the dam and restore critical habitat for the steelhead trout.

"From an engineering and environmental perspective, this is a landmark project," said California American Water president Rob MacLean. "Our innovative method for dealing with the sedimentation behind the dam and the level of public-private cooperation which has made this plan a reality will serve as a template for the removal of other obsolete dams across the country."

California American Water is partnering with the National Oceanic and Atmospheric Administration's National Marine Fisheries Service and the California State Coastal Conservancy to implement the dam removal project while minimizing cost to its ratepayers. California American Water has committed $49 million and the dedication of 928 acres where the dam is located as parkland.

The Coastal Conservancy and NOAA committed to raise the additional $35 million needed for the removal project through a combination of public funding and private donations.

The San Clemente Dam is a 106ft high concrete-arch dam built in 1921, 18 miles from the ocean on the Carmel River, to supply water to the Monterey Peninsula's then-burgeoning population and tourism industry. Today the reservoir is over 90 percent filled with sediment and has a limited water supply function.

In 1991, the California Department of Water Resources, Division of Safety of Dams agreed with a California American Water consultant's assertion that San Clemente Dam did not meet modern seismic stability and flood safety standards.

The Department of Water Resources and Army Corps of Engineers studied many ways to ameliorate the safety issues including strengthening the dam and removing it.

The January 2008 Final Environmental Impact Report and Environmental Impact Statement ("EIR/EIS") regarding San Clemente Dam's stability contains analysis of a Reroute and Removal Project, which would address the seismic and flood safety risks associated with San Clemente Dam by permanently rerouting a portion of the Carmel River and removing the dam.

Under this proposal, the Carmel River would be rerouted to bypass the 2.5 million cubic yards of silt that have accumulated behind the dam thereby avoiding dredging, which has been deemed infeasible.

The primary benefits of the Reroute and Removal Project are that it improves the Carmel River environment by removing the dam, which serves as a barrier to fish passage, and satisfies government agencies' concerns that strengthening the dam, as opposed to removing it, could further threaten the South Central California Coast Steelhead and violate the federal Endangered Species Act.

Source: Dredging News Online 2010

Box 26-6 Case Study: Clear Lake — Algae in Clear Lake

The Clear Lake Basin was shaped by a variety of processes over the last 1 to 2 million years. Scientists have recovered a nearly continuous sequence of lake sediments dating back 475,000. Other lake sediments in the region that date back to the Early Pleistocene, approximately 1.6-1.8 million years ago.

There is an excellent climate record from these cores for the last 127,000 years. The record documents a shift from pine dominated to oak dominated forests at the end of the Pleistocene Glacial Period 10,000 years ago, indicating a warming trend. The diatom sequence in these cores indicate that Clear Lake has been a shallow, productive system, essentially similar to the modern lake since the end of the Pleistocene Period.

The basin was created primarily from the stresses of the San Andreas Fault System, the eruption and subsidence of the Clear Lake Volcanics, and the erosion and deposition of the parent rock. The east-west extension of the fault system and vertical movements of the faults created and maintained the basin. Downward vertical movement within the basin created by these processes is at a rate approximately equal to the average sedimentation rate of 1/25 inch/year in the lake basin.

Since these rates are essentially equal, a shallow lake has existed in the upper basin for at least the last 475,000 years. If sedimentation rates were significantly different from the downshift, then either a deepwater lake or a valley would have resulted. Although the lake has changed shape significantly over this period, it has generally been located in the same area as the existing Upper Arm.

Clear Lake is a naturally eutrophic lake. Eutrophic lakes are nutrient rich and very productive, supporting the growth of algae and aquatic plants (macrophytes). Factors contributing to its eutrophication include a fairly large drainage basin to contribute mineral nutrients to the water, shallow and wind mixed water, and no summertime cold water layer to trap the nutrients. Because of the lake's productivity, it also supports large populations of fish and wildlife.

The algae in Clear Lake are part of the natural food chain and keep the lake fertile and healthy. Because of the lake's relative shallowness and warm summer temperatures, the algae serve another important purpose. They keep the sun's rays from reaching the bottom, thus reducing the growth of water weeds which would otherwise choke off the lake.

Along with Clear Lake's high productivity, algae in the lake can create a situation which can be perceived as a problem to humans. Algae are tiny water plants that cycle normally between the bottom and the surface, floating up and sinking down. During the day, algae generate oxygen within the lake; at night they consume oxygen.

Nuisance blue-green algae, however, can be a problem. From more than 130 species of algae identified in Clear Lake, three species of blue-green algae can create problems under certain conditions. These problem blue-greens typically "bloom" twice a year, in spring and late summer. The intensity of the blooms vary from year to year, and are unpredictable. The problem occurs when algae blooms are trapped at the surface and die. When this occurs, unsightly slicks and odors can be produced.

It does not appear that blue-green algae are a recent development in Clear Lake.

Sediment cores collected from the bottom of Clear Lake by the United States Geological Survey (USGS) indicate Clear Lake has been eutrophic with high algal populations since the last ice age, which ended approximately 10,000 years ago. The graph at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Algae+Pollen+in+Core.pdf shows the change in algae pollen over time from a core in the Upper Arm.

Livingston Stone, a fisheries biologist, visited Lake County in 1873 and reported to Congress that Clear Lake had significant algal populations at the time.

> It is a singular fact, illustrating the inaptness with which names are often given to natural objects, that the water of Clear Lake is never clear. It is so-cloudy, to use a mild word, that you cannot see three feet below the surface. The color of the water is a yellowish brown, varying indefinitely with the varying light. The water has an earthy taste, like swamp-water, and is suggestive of moss and water-plants. In fact, the bottom of the lake, except in deep places, is covered with a deep, dense moss, which sometimes rises to the surface, and often to such an extent in summer as to seriously obstruct the passage of boats through the water.

He further describes water conditions in September as:

> Fish and fishing are about the same as in August. The weather is a little warmer. No one fishes during this month except the Indians, who still keep after the trout. The water this mouth is in its worst condition. It is full of the frothy product of the soda-springs. A green scum covers a large part of the surface, and it is not only uncleanly to look at, but unfit to drink; and yet, strangely enough, this lake, which one would think uninhabitable by fish, fairly teems and swarms with them.

These descriptions appear to describe blue-green algae and conditions similar to that in the last 20 years. The “moss” described in the first passage could be rooted plants or the filamentous algae *Lyngbya*, which behaves in a similar manner. Regardless, this moss indicates a relatively clear lake if sunlight is penetrating sufficiently to promote growth of “moss” on the bottom. The full text of Stone’s writings about Clear Lake are available at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Livingston+Stone.pdf.

Other historical accounts indicate the lake was relatively clear through 1925. Substantial declines in clarity and increases in scum forming algae (blue-green algae) occurred between 1925 and 1939. An increase in nutrient loading from increased erosion, fertilizer and wastewater discharges due to urban and agricultural development were the probable causes of increased blue-green algal growth.

The advent of powered earthmoving equipment increased the amount of soil disturbance and facilitated large construction projects, such as the Tahoe-Ukiah Highway (State Highway 20), the reclamation of the Robinson Lake floodplain south of Upper Lake, stream channelization and the filling of wetlands along the lake perimeter. To support the development, gravel mining increased within the streams , further increasing erosion and sediment delivery to Clear Lake. During this time period, mining techniques at the Sulphur Bank Mercury Mine changed from shaft mining to strip mining, resulting in the discharge of tens of thousands of yards of overburden directly into Clear Lake.

Limnological studies of Clear Lake began in the early 1960’s to determine the causes of the high productivity in Clear Lake. It was found that the lake is nitrogen limited in the summer, with a great excess of phosphorus within the system. Phosphorus in the water column comes from both the annual inflows and nutrient cycling from the lake sediments. Nitrogen limitation does not affect many blue-green algae, as they were able to utilize (fix) nitrogen from the atmosphere, and consequently have an essentially unlimited supply of nitrogen. This gave these blue-green algae a competitive advantage, and *Anabaena* and *Aphanizomenon* dominated the lake during the summer. A third blue-green algae, Microcystis, also occurred in significant quantities. During this time period, it was also determined that iron was a limiting micro-nutrient.

Starting in the summer of 1990, lake clarity improved significantly. This improved clarity has continued until the present. The graph at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Secchi+Depth$!2c+Upper+Arm.pdf shows the Secchi Depth (the depth into the water at which a black and white checked plate is visible) in the Upper Arm from 1969 through 2008.

During the 1991-1994 time period, University of California researchers led by Drs. Peter Richerson and Thomas Suchanek analyzed lake water quality data collected for the previous 15 years, conducted experiments and evaluated the Clear Lake system. Unfortunately, little data was available during the period of improved clarity since 1990. The “Clean Lakes Report” (http://www.co.lake.ca.us/Assets/WaterResources/Algae/Clean+Lakes+Report$!2c+1994.pdf) determined that excess phosphorus is a major cause, however, iron limits the growth of blue-green algae. The improved water clarity and reduced blue-green algal blooms continued into the new millennium. DWR data collected since the Clean Lakes Report was evaluated by Lake County staff in 2002. Surprisingly, phosphorus and total nitrogen concentrations in the lake did not change substantially when the lake clarity increased. Cursory review of the data did not provide evidence of chemical changes that led to the improved clarity and reduced blue-green algal blooms in Clear Lake.

Source: County of Lake 2010